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SECOND SPECTRUM OF HAFNIUM (Hf II)

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ABSTRACT

New data (wave-length measurements and intensity estimates) for more than 1,000 lines characteristic of singly ionized hafnium atoms, including Zeeman patterns for 207 lines, are presented. Analysis has resulted in the interpretation of 862 lines as combinations of 117 atomic energy states, most of which are grouped and identified as doublet or quartet spectral terms. The normal state of the Hf^+ ion is represented by a doublet-D term arising from the electron configuration $5d\ 6s^2$, and a tentative value of 14.8 volts is derived for the ionizing potential. Attention is called to the extraordinary similarity between La I and Hf II spectra.

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I. INTRODUCTION

An improved description of hafnium spectra, published in 1928 by Meggers,[1] included data on wave lengths and intensities of about 1,500 lines between the limits 2155.72 A in the ultraviolet and 9250.27 A in the infrared. The range of this list, the precision of the wave-length measurements, and especially the discrimination between lines characterizing neutral atoms (Hf I) and those due to ionized atoms (Hf II) gave the present authors an incentive to search for regularities in the first two spectra of hafnium. Such regularities were indeed found, and preliminary reports of the structures of these spectra have been published.[2] In each case relative energy levels were established which combined in such manner as to account for more than 200 spectral lines and permit the assignment of relative values of inner-quantum numbers to the levels. The absolute values of these quantum numbers were tentatively fixed on the basis of suggested identifications of the ground states; thus, from theoretical considerations and comparison with similar spectra, the lowest term for Hf I was assumed to be $(d^2s^2)^3F$, while for Hf II it was $(ds^2)^2D$. A study of the electric furnace spectrum of hafnium by King [3] confirmed our separation of Hf II from Hf I lines and indicated that our Hf I levels were correctly oriented.

At this stage it was felt that, to verify our identification of the ground states and to extend such identifications to the remaining

[1] W. F. Meggers, BS J.Research 1,151(1928);RP51.
[2] W. F. Meggers and B. F. Scribner, J.O.S.A. & R.S.I. 17,83(1928), Hf II. W. F. Meggers and B.F. Scribner, BS J.Research 4,169(1930)RP139; Hf I.
[3] A. S. King, Astrophys. J. 70,343(1929).

levels, observations on the behavior of hafnium lines in a magnetic field were indispensible. Such a study of the Zeeman effect for hafnium [4] was made possible by Dr. G. Holst, of Eindhoven, Holland, who kindly presented for this purpose a small rod of hafnium metal condensed on a tungsten filament. From this investigation we obtained new data for 280 hafnium lines (2393 to 4817 A), 70 belonging to the first and 210 to the second spectrum. Analysis of these Zeeman patterns confirmed our first suggested identifications of the low energy states, and made it possible to extend the spectral classifications, especially for Hf II lines since a larger proportion of the latter appeared in the magnetic field.

On account of the position of hafnium in the periodic table of chemical elements (immediately following the rare earth group) its spectral structures are of special interest and it is highly desirable to make these analyses as nearly complete as possible. For the Hf II analysis, it was soon found that a limitation was imposed by the restricted range for which data were available and in part by the fact that the earlier observations were made with impure materials. Thus in the work already mentioned,[5] although 2,100 lines were measured in the interval 2165 to 9250 A, more than 600 of these were discarded as evidence of columbium, zirconium, titanium, and other impurities. A more reliable and extended list of hafnium lines was finally obtained through the kind cooperation of Prof. G. von Hevesy, who, in 1932, supplied us with a sample of highly purified oxide, with which the spectra have been reobserved, and extended to 1990 A in the ultraviolet and to 10637 A in the infrared. A further extension in the ultraviolet was made by Dr. R. J. Lang of the University of Alberta, who photographed the spark spectra to 1300 A using the same electrodes which the authors employed for the study of Zeeman effects. To give a detailed account of the new experiments and to present the final results for the Hf II spectrum are the aims of the present paper. Further data and analysis of the Hf I spectrum will be published after they have been supplemented by additional observations of Zeeman effects, since the data at present available have proved insufficient for the complete identification of Hf I spectral terms.

II. WAVE-LENGTH MEASUREMENTS AND INTENSITY ESTIMATES

The new sample of hafnium oxide presented by Professor Hevesy (1932) for the continuation of our spectroscopic studies, greatly surpassed the earlier one (1925) in purity. Whereas the first sample was relatively rich in columbium, zirconium, and titanium (represented by 357, 109, and 50 lines, respectively) the last one was entirely free from titanium and showed only a spectroscopic trace of columbium, but contained considerable amounts of zirconium and nickel.

In making spectrograms with this new material, the same instruments and technic were employed as in the earlier experiments fully described elsewhere.[6] In addition to arc and spark exposures made with silver electrodes on which a portion of hafnium salt was fused, the entire range of spectrum was also investigated with very pure copper electrodes. However, in the latter case, it was found im-

[4] W. F. Meggers and B. F. Scribner, J.O.S.A. 23,121(1933).
[5] W. F. Meggers, BS J.Research 1,151(1928);RP151.
[6] W. F. Meggers, BS J.Research 1,153(1928);RP151.

possible to observe the spark spectrum because of the ease with which the oxides scaled off, so stigmatic arc images were recorded full length and enhancement at the cathode was relied upon as an indication of ionization. Besides serving as a check on the observations with silver electrodes, those with copper electrodes revealed some lines which had previously been overlooked because of masking by silver lines.

The later spectrograms were, in general, stronger exposures so that it was necessary to revise the scale of estimated intensities formerly given. By using Schumann plates in the ultraviolet, the authors succeeded in extending the observations from 2155 A to 1990 A with a Hilger E_1 quartz spectrograph, and Dr. Lang recorded the spark spectrum to 1300 A with his vacuum spectrograph containing a concave grating of 2 meters radius. New photographic plates which first became available about 3 years ago permitted extension of observations in the infrared to 10637 A. Formerly no satisfactory spark exposures of hafnium were obtained for waves longer than 6000 A, but after 5 trials with the new material one was obtained which revealed enhanced lines (greater intensity in spark than in arc) up to about 7000 A. Beyond this point, lines arising from ionized atoms can only be recognized by their enhancement at the negative electrode of the arc. The same applies to lines in a portion of the ultraviolet (2000 to 2400 A) where our spark spectrograms were relatively weak. In this range, the Hf II spectrum is well developed at the arc cathode, and all lines truly enhanced in spark spectrograms probably belong to twice ionized atoms.

Our final estimates of relative intensities of halnium lines are based entirely upon the new observations, but the earlier values for wave lengths were averaged with the most recent determinations, with the hope that the final means thus derived from 4 to 7 or 8 spectrograms would be improved in precision of relative value.

III. OBSERVATIONS OF ZEEMAN EFFECTS

For the study of Zeeman effects on hafnium lines, we employed electrodes of hafnium metal condensed on a tungsten filament. The electrodes were mounted in brass supports between the pole pieces of a Weiss electromagnet made by the Geneva Society, and the spark was operated with a condensed discharge from an alternating-current transformer. After passing through a Wollaston prism of crystal quartz, the light was focused on the slit of a stigmatic concave grating spectrograph by means of a lens of fused quartz. This enabled us to photograph both parallel and perpendicular components of the transverse Zeeman effect simultaneously. Several spectrograms were made on Eastman 33 plates in the second order of a Rowland grating giving a dispersion of 1.8 A per mm, and covered the range from 2300 to 4900 A. Unfortunately, the hafnium metal oxidized and wore away rather rapidly in the atmospheric spark, so that tungsten lines finally appeared with predominating intensity and too little of the hafnium remainded for observation of Zeeman effects in the region of longer waves.

A field strength of about 33,000 gausses was maintained with a pole gap of 6 mm, the actual field strength for each exposure being determined from measurements either of calcium lines (3933, 3968 A) due

to contamination of the hafnium electrodes, or of aluminum (3944, 3962 A) or zinc lines (4680, 4722, 4810 A) impressed immediately before or after the hafnium exposure. Under the most favorable conditions of exposure and intensity distribution, we were able to resolve patterns in which the separations are about $a/8$ but the limit is more commonly around $a/5$. Patterns which are fully resolved are followed in importance by those in which the components are blended, but show typical intensity gradients. It has been customary to distinguish at least 3 different types represented by symbols A^1, A^2, and B, according as the strongest perpendicular (n) components are inside, outside, and in the center of the group, respectively. Whenever the type of unresolved pattern was obviously A, we attempted to measure the separations of the strongest components, but when no asymmetry was noticed, we assume that the measured separations apply to the centroids of the pattern. In the latter case, measurements are found to deviate about 25 percent of the total range of separations from the value for the components of greatest intensity.

IV. CLASSIFICATION OF Hf II LINES

In our preliminary account of regularities in the spark spectrum of hafnium [7] we displayed 206 combinations between 16 levels of low energy and 27 higher ones. The 2 lowest levels were tentatively named $(ds^2)^2D$, and the next 4 were regarded as $(d^2s)^4F$ but further attempts at grouping and identifying levels were considered too hazardous. As soon as the new data on Zeeman effects were available, the tentative interpretation of Hf II levels was confirmed, and the g values (splitting factors) for all of the remaining established levels were calculated from resolved patterns. This made it relatively easy to group levels into terms and configurations, which in turn indicated which terms were still missing and where they should be sought.

In this way the table of combinations was extended to include about 800 lines involving 32 levels of the first set and 70 of the second or middle set. At this point, the lines which remained unclassified were mainly faint and hazy ones, so that attention was then turned to the search for third set levels which might be expected as spectral terms forming series with the lower ones. A number of such high levels have been established but their proper grouping and interpretation are uncertain, since none of them combine strongly enough to be tested with Zeeman effects, and nothing is known at present of the structure of the Hf III spectrum, the low terms of which represent the convergence limits of Hf II series.

Soon after the already published Hf II levels were definitely identified by means of Zeeman effects and grouped into doublet and quartet terms, it was noticed that a remarkable parallelism existed between the structures of Hf II and La I spectra. Not only the relative positions of the terms but level separations and abnormalities in interval ratios and inversions are more or less faithfully duplicated (except for a scale factor) in Hf II as found [8] in La I. This close similarity of the two spectra served as a guide in the further analysis of the Hf II spectrum; it will be discussed in more detail in the last section of this paper.

[7] W. F. Meggers and B. F. Scribner, J.O.S.A. & R.S.I. **17**,83(1928).
[8] H. N. Russell and W. F. Meggers, BS J.Research **9**,647 (1932); RP497.

Complete data for Hf II lines are presented in table 1, where measured wave lengths, estimated intensities, wave numbers in vacuum, term combinations, observed and calculated Zeeman effects appear in successive columns. Of the 1,035 lines listed in table 1 as characteristic of singly ionized hafnium atoms, 862 have been classified as combinations of 117 atomic energy levels, most of which have been grouped into doublet or quartet spectral terms. These terms combine in such a way that the simple selection rule for total angular momenta or so-called inner quantum numbers ($\Delta J=0, \pm 1$) is strictly obeyed, but there is apparently no restriction on changes in orbital momenta, ΔL (except that imposed by the ΔJ rule) and combinations occur for $\Delta L=0, \pm 1, \pm 2, \pm 3$. Intersystem combinations are very prominent and, except for more frequent intensity anomalies, follow the same rules as doublets or quartets. It is obvious that a satisfactory analysis of such a spectrum would have been impossible without the aid of Zeeman effects.

In the extreme ultraviolet only the classified lines have been quoted from Lang's observations. The unclassified lines in table 1, which are situated mainly in the ultraviolet, are relatively faint and usually hazy and unsymmetrical in the spark. Their wave lengths are derived from arc spectrograms in which they appear as electrode lines. These lines probably represent combinations with high levels which it is impossible to establish or identify from the limited data at hand.

In the last column of table 1, we have entered computed Zeeman patterns for comparison with the observed patterns reported in the preceding column. The computed patterns were obtained by applying the ordinary rules to the g values derived from the observations; they are here given in complete detail to permit a critical test of the quality and consistency of the observations, and also to facilitate comparison with tables of theoretical Zeeman effects computed by Kiess and Meggers [9] for pure LS coupling. The splitting factors for Hf II levels deviate so often and so widely from the Landé values that they may be regarded as a new system representative of vector coupling of a mixed or intermediate type.

TABLE 1.—*First spark spectrum of hafnium* (Hf II)

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
9742.28	10	(?)	10261.73	$b^4F_{1½}$—$z^4D^0_{0½}$		
9453.55	2	(?)	10575.14	$b^2F_{2½}$—$z^2D^0_{1½}$		
8581.88	1	5?	11649.26	$b^4F_{2½}$—$z^4D^0_{1½}$		
8305.91	2	4	12036.32	$b^2D_{2½}$—$z^4F^0_{2½}$		
8236.13	5	10	138.29	$b^4F_{3½}$—$z^4F^0_{3½}$		
7983.66	3	5	522.14	$a^2H_{4½}$—$y^4F^0_{3½}$		
7861.22	3	8	717.18	$b^4F_{3½}$—$z^4D^0_{2½}$		
7801.53	2	6	814.48	$a^2P_{0½}$—$z^4F^0_{1½}$		
7757.89	5	15	886.56	$b^4F_{1½}$—$z^4D^0_{1½}$		
7720.72	1	2	12948.60	$b^2G_{3½}$—$z^2F^0_{3½}$		
7663.09	2	30	13045.98	$b^4F_{2½}$—$z^2D^0_{2½}$		
7634.50	1	1	094.83	$b^2P_{1½}$—$y^4P^0_{1½}$		
7565.35	—	2	214.73	$b^4P_{2½}$—$y^2D^0_{2½}$		
61.08	1	10	221.99	$b^4P_{1½}$—$z^4P^0_{2½}$		
7514.88	—	2	303.27	$b^2G_{3½}$—$y^2D^0_{2½}$		

[9] C. C. Kiess and W. F. Meggers, BS J.Research **1**, 641 (1928);RP23.

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
7398.96	—	10	511.70	$b^2F_{2\frac{1}{2}}$—$x^2F^o_{2\frac{1}{2}}$		
7328.64	3	30	641.34	$b^4F_{2\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$		
7292.33	1	1	709.27	$b^2D_{1\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$		
78.72	—	6	734.90	$b^2D_{1\frac{1}{2}}$—$w^2D^o_{1\frac{1}{2}}$		
7277.67	5	50	736.88	$b^4F_{4\frac{1}{2}}$—$z^4D^o_{3\frac{1}{2}}$		
7189.30	1	3	905.73	$a^2P_{0\frac{1}{2}}$—$z^4D^o_{0\frac{1}{2}}$		
7164.52	1	5	13953.83	$a^2P_{1\frac{1}{2}}$—$z^4D^o_{1\frac{1}{2}}$		
7061.90	10	30?	14156.60			
30.33	30	150	220.17	$b^4F_{2\frac{1}{2}}$—$z^4D^o_{2\frac{1}{2}}$		
21.23	3	30	238.60	$b^4F_{1\frac{1}{2}}$—$z^2P^o_{0\frac{1}{2}}$		
16.99	—	6	247.20	$a^2H_{4\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$		
7010.68	5	10?	260.03			
6997.83	2	20	286.21	$b^2G_{4\frac{1}{2}}$—$z^4G^o_{4\frac{1}{2}}$		
80.91	100	200	320.84	$a^2F_{3\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$		
70.44	5	10?	342.35			
6935.16	5	50	415.31	$b^2D_{2\frac{1}{2}}$—$z^4D^o_{1\frac{1}{2}}$		
6857.03	5	10?	579.56			
55.29	7	50	583.26	$a^4P_{2\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$		
6850.07	20	60?	594.37			
6767.91	1	1	771.54	$b^2P_{1\frac{1}{2}}$—$x^2P^o_{0\frac{1}{2}}$		
54.61	60	100	800.63	$b^2D_{1\frac{1}{2}}$—$z^4D^o_{0\frac{1}{2}}$		
6719.40	2	50	14900.36	$b^2F_{3\frac{1}{2}}$—$x^2F^o_{3\frac{1}{2}}$		
6647.06	30	100	15040.10	$b^4F_{4\frac{1}{2}}$—$z^4F^o_{4\frac{1}{2}}$		
44.60	100	200	045.67	$b^2D_{1\frac{1}{2}}$—$z^4F^o_{2\frac{1}{2}}$		
09.20	1	8	126.25	$c^2D_{2\frac{1}{2}}$—$y^4D^o_{2\frac{1}{2}}$		
6605.91	—	1	133.79	$b^4P_{2\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$		
6599.76	1	4	147.89	$a^4P_{1\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$		
84.53	4	40	182.93	$a^2H_{5\frac{1}{2}}$—$y^4F^o_{4\frac{1}{2}}$		
67.39	6	60	222.55	$b^2G_{3\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$		
65.76	—	3	226.33	$b^4F_{1\frac{1}{2}}$—$z^2D^o_{1\frac{1}{2}}$		
62.86	2	10	233.06	$b^4P_{1\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$		
57.91	10	100	244.56	$b^4F_{3\frac{1}{2}}$—$z^4D^o_{3\frac{1}{2}}$		
50.01	1	10	262.94	$b^2F_{3\frac{1}{2}}$—$w^2D^o_{2\frac{1}{2}}$		
48.72	1	10	265.95			
48.24	2	3	267.07	$a^2H_{5\frac{1}{2}}$—$z^4G^o_{5\frac{1}{2}}$		
42.80	3	50	279.76	$a^2H_{4\frac{1}{2}}$—$z^2G^o_{4\frac{1}{2}}$		
31.66	2	30	305.82	$a^2P_{1\frac{1}{2}}$—$z^2P^o_{0\frac{1}{2}}$		
26.20	—	5	318.63	$b^2F_{2\frac{1}{2}}$—$x^4D^o_{1\frac{1}{2}}$ $b^4P_{2\frac{1}{2}}$—$y^2F^o_{2\frac{1}{2}}$		
12.61	1	10	350.59	$a^2P_{1\frac{1}{2}}$—$z^2D^o_{2\frac{1}{2}}$		
6511.62	—	6	352.93	$b^4F_{4\frac{1}{2}}$—$z^4G^o_{3\frac{1}{2}}$		
6494.58	—	5	393.21			
73.89	3	20	442.41	$b^2G_{3\frac{1}{2}}$—$y^2F^o_{2\frac{1}{2}}$		
67.90	2	2	456.71	$b^4F_{1\frac{1}{2}}$—$z^4D^o_{2\frac{1}{2}}$		
62.30	1	4	470.10	$a^2G_{3\frac{1}{2}}$—$z^2D^o_{2\frac{1}{2}}$		
6455.85	2	20	485.56	$b^4P_{1\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$		
6390.99	1	2	642.71			
90.32	1	2	644.35			
43.77	1	4	759.15	$b^4P_{1\frac{1}{2}}$—$y^2P^o_{0\frac{1}{2}}$		
37.76	—	1	774.09	$b^4P_{0\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$		
15.94	1	5	828.59	$b^2F_{2\frac{1}{2}}$—$w^2F^o_{3\frac{1}{2}}$		
6306.17	1	5	853.11	$b^4P_{2\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$		
6279.84	15	20	919.58	$a^4P_{2\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$		
71.05	1	3	941.89	$b^2G_{3\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$		
48.95	80	100	15998.27	$a^2F_{2\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$		
30.84	10	20	16044.77	$b^4F_{1\frac{1}{2}}$—$z^4G^o_{2\frac{1}{2}}$		
29.66	2	3	047.81	$b^4P_{0\frac{1}{2}}$—$y^2P^o_{0\frac{1}{2}}$		
22.81	6	10	065.47	$a^2G_{3\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$		
06.95	1	3	106.53	$b^2F_{3\frac{1}{2}}$—$z^2H^o_{4\frac{1}{2}}$		
6202.85	2	2	117.17	$a^4P_{0\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$		
6158.72	1	2	232.66	$b^2G_{3\frac{1}{2}}$—$y^2F^o_{3\frac{1}{2}}$		
56.25	3	3 d	239.17	$a^4P_{1\frac{1}{2}}$—$z^4D^o_{0\frac{1}{2}}$ $b^4F_{2\frac{1}{2}}$—$z^2P^o_{1\frac{1}{2}}$		
35.65	1	1	293.69	$a^2P_{1\frac{1}{2}}$—$z^2D^o_{1\frac{1}{2}}$		
6135.10	10	20	295.15	$b^2G_{4\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$		
6097.47	—	2	395.72	$b^4P_{1\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$		
93.15	—	2	407.34	$b^2D_{2\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
48.00	3	5	529.82	$a^2P_{0\frac{1}{2}}$—$z^4D^\circ_{1\frac{1}{2}}$		
41.44	2	6	547.77	$b^4F_{3\frac{1}{2}}$—$z^4F^\circ_{4\frac{1}{2}}$		
31.96	1	3	573.78	$b^2F_{2\frac{1}{2}}$—$y^2G^\circ_{3\frac{1}{2}}$		
27.57	10	20	585.85	$b^2G_{4\frac{1}{2}}$—$y^2F^\circ_{3\frac{1}{2}}$		
6006.39	2	2	644.34	$a^2G_{3\frac{1}{2}}$—$z^4D^\circ_{2\frac{1}{2}}$		
5969.38	4	5	747.53	$b^4F_{2\frac{1}{2}}$—$z^4D^\circ_{3\frac{1}{2}}$		
5929.35	3	5	860.59	$b^4F_{3\frac{1}{2}}$—$z^4G^\circ_{3\frac{1}{2}}$		
5885.58	3 Zr?	2	985.98	$b^2D_{2\frac{1}{2}}$—$z^4D^\circ_{3\frac{1}{2}}$		
42.23	50	80	112.02	$a^2P_{1\frac{1}{2}}$—$z^4G^\circ_{2\frac{1}{2}}$		
09.50	20	30	208.42	$a^4P_{0\frac{1}{2}}$—$z^4D^\circ_{0\frac{1}{2}}$		
5801.71	7	15	231.53	$a^2G_{3\frac{1}{2}}$—$z^4G^\circ_{2\frac{1}{2}}$		
5767.18	15	30	334.70	$a^2F_{2\frac{1}{2}}$—$z^4F^\circ_{2\frac{1}{2}}$		
5752.53	3	5	378.85			
5373.58	4	10	620.68	$b^2F_{3\frac{1}{2}}$—$x^4P^\circ_{2\frac{1}{2}}$		
60.40	—	1	661.71	$b^2F_{2\frac{1}{2}}$—$x^4P^\circ_{2\frac{1}{2}}$		
58.83	1	3	666.61	$b^2G_{3\frac{1}{2}}$—$y^4F^\circ_{4\frac{1}{2}}$		
5631.36	1	4	752.78	$b^2P_{1\frac{1}{2}}$—$x^2P^\circ_{1\frac{1}{2}}$		
5590.73	3	5	881.80	$a^2P_{0\frac{1}{2}}$—$z^2P^\circ_{0\frac{1}{2}}$		
65.56	2	5	17962.67	$a^2H_{4\frac{1}{2}}$—$z^2G^\circ_{4\frac{1}{2}}$		
47.83	—	1	18020.07	$b^2G_{4\frac{1}{2}}$—$y^4F^\circ_{4\frac{1}{2}}$		
24.35	40	50	096.66	$a^2F_{3\frac{1}{2}}$—$z^2D^\circ_{2\frac{1}{2}}$		
5514.96	1	3	127.47	$b^4P_{2\frac{1}{2}}$—$y^4D^\circ_{1\frac{1}{2}}$		
5493.22	1	6	199.21	$b^2F_{3\frac{1}{2}}$—$y^2G^\circ_{4\frac{1}{2}}$		
63.38	10?	10	298.62	$a^4P_{2\frac{1}{2}}$—$z^4D^\circ_{1\frac{1}{2}}$		
44.07	20	30	363.52	$b^4F_{2\frac{1}{2}}$—$z^4G^\circ_{3\frac{1}{2}}$		
30.06	1	4	410.90			
5420.44	2	3	443.58	$b^4F_{2\frac{1}{2}}$—$z^2F^\circ_{2\frac{1}{2}}$		
5391.36	6	10	543.05	$a^2P_{1\frac{1}{2}}$—$z^2P^\circ_{1\frac{1}{2}}$		
71.80	2	4	610.57	$b^4P_{2\frac{1}{2}}$—$z^2G^\circ_{3\frac{1}{2}}$		
61.38	1	2	646.74	$b^4P_{0\frac{1}{2}}$—$y^4D^\circ_{0\frac{1}{2}}$		
48.40	10	15	692.00	$a^2F_{3\frac{1}{2}}$—$z^4F^\circ_{3\frac{1}{2}}$		
46.30	10	40	699.34	$b^2G_{3\frac{1}{2}}$—$z^2G^\circ_{3\frac{1}{2}}$		
24.26	20	30	776.74	$b^2D_{1\frac{1}{2}}$—$z^2P^\circ_{0\frac{1}{2}}$		
5311.60	100	150	821.50	$b^2D_{1\frac{1}{2}}$—$z^2D^\circ_{2\frac{1}{2}}$		
5299.85	8	10	863.22	$a^4P_{1\frac{1}{2}}$—$z^4D^\circ_{1\frac{1}{2}}$		
98.06	80	100	869.60	$a^2P_{0\frac{1}{2}}$—$z^2D^\circ_{1\frac{1}{2}}$		
89.98	3	10	898.42	$a^2H_{5\frac{1}{2}}$—$z^2G^\circ_{4\frac{1}{2}}$		
76.39	1	3	947.09	$b^2F_{2\frac{1}{2}}$—$w^2P^\circ_{1\frac{1}{2}}$		
64.95	50	80	18988.26	$b^4F_{1\frac{1}{2}}$—$y^2D^\circ_{1\frac{1}{2}}$		
60.44	30	40	19004.54	$b^2D_{2\frac{1}{2}}$—$z^2P^\circ_{1\frac{1}{2}}$		
5247.10	40	60	052.86	$b^2G_{4\frac{1}{2}}$—$z^2G^\circ_{3\frac{1}{2}}$		
5194.57	3	6	245.53	$b^4F_{4\frac{1}{2}}$—$z^4G^\circ_{4\frac{1}{2}}$		
87.75	20	30	270.83	$a^2F_{3\frac{1}{2}}$—$z^4D^\circ_{2\frac{1}{2}}$		
64.56	3	8	357.36	$b^4P_{2\frac{1}{2}}$—$y^4D^\circ_{2\frac{1}{2}}$		
56.06	1	5	389.17	$b^4P_{1\frac{1}{2}}$—$y^4D^\circ_{1\frac{1}{2}}$		
28.53	10	20	493.35	$a^2G_{4\frac{1}{2}}$—$z^4D^\circ_{3\frac{1}{2}}$		
27.08	--	1	498.87	$b^4P_{0\frac{1}{2}}$—$z^2S^\circ_{0\frac{1}{2}}$		
5110.61	--	7	561.70	$c^2D_{2\frac{1}{2}}$—$x^2F^\circ_{3\frac{1}{2}}$		
5080.44	2	10	677.87	$b^4P_{0\frac{1}{2}}$—$y^4D^\circ_{1\frac{1}{2}}$		
79.65	40	60	680.92	$b^4F_{1\frac{1}{2}}$—$z^2F^\circ_{2\frac{1}{2}}$		
75.92	10	20	695.39	$a^4P_{2\frac{1}{2}}$—$z^2D^\circ_{2\frac{1}{2}}$		
71.23	6	8	713.60	$a^2F_{2\frac{1}{2}}$—$z^4D^\circ_{1\frac{1}{2}}$		
58.18	8	10	764.46	$b^2D_{1\frac{1}{2}}$—$z^2D^\circ_{1\frac{1}{2}}$		
57.03	20	30	768.96	$b^4F_{3\frac{1}{2}}$—$z^2F^\circ_{3\frac{1}{2}}$		
40.82	100	150	832.53	$a^4P_{0\frac{1}{2}}$—$z^4D^\circ_{1\frac{1}{2}}$		
5034.33	4	8	858.09	$a^2F_{3\frac{1}{2}}$—$z^4G^\circ_{3\frac{1}{2}}$		
4999.69	30	40	19995.68	$b^2D_{1\frac{1}{2}}$—$z^4D^\circ_{2\frac{1}{2}}$		
84.78	1	3	20055.49	$a^2P_{1\frac{1}{2}}$—$y^2D^\circ_{1\frac{1}{2}}$		
45.38	7	10	215.27	$a^4P_{1\frac{1}{2}}$—$z^2P^\circ_{0\frac{1}{2}}$		
34.46	50	60	260.00	$a^4P_{1\frac{1}{2}}$—$z^2D^\circ_{2\frac{1}{2}}$		
26.99	6	8	290.72	$a^4P_{2\frac{1}{2}}$—$z^4F^\circ_{3\frac{1}{2}}$		
20.97	2	5	315.54			
07.34	1	3	371.97	$b^4F_{2\frac{1}{2}}$—$z^4P^\circ_{2\frac{1}{2}}$		
4904.51	10	30	383.72	$b^4P_{2\frac{1}{2}}$—$y^4D^\circ_{3\frac{1}{2}}$		
4885.75	1	6	461.99	$a^2H_{4\frac{1}{2}}$—$x^2F^\circ_{3\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
83.26	—	4	472.42	$b^2G_{3½}$—$y^4D^o_{3½}$		
65.43	5	10	547.45	$b^2G_{3½}$—$x^2D^o_{2½}$		
60.54	1	3	568.12	$a^2P_{1½}$—$z^4P^o_{½}$		
48.46	4	20	619.36	$b^4P_{1½}$—$y^4D^o_{2½}$		
44.00	10	15	638.35	$a^4P_{2½}$—$z^2D^o_{1½}$		
34.84	—	2	677.45	$b^2F_{3½}$—$v^2D^o_{2½}$		
17.22	20	80	753.08	$b^4F_{3½}$—$z^4G^o_{4½}$	(0.00 w) 1.09	(0.03, 0.09, 0.15, 0.21) 0.96, 1.02, 1.08, 1.14, 1.20, 1.26, 1.32, 1.38
09.18	4	6	787.77	$a^2G_{3½}$—$z^4G^o_{3½}$		
4807.14	15	20	796.60	$a^2G_{4½}$—$z^4F^o_{4½}$		
4790.72	15	40	867.87	$a^2G_{3½}$—$z^2F^o_{2½}$		
65.78	2	12	977.08	$b^4P_{0½}$—$x^2D^o_{1½}$		
60.59	4	20	20999.95	$b^4P_{0½}$—$z^4S^o_{1½}$		
49.39	—	1	21049.47	$b^2F_{2½}$—$x^4D^o_{3½}$		
35.75	—	10	110.10	$a^2G_{4½}$—$z^4G^o_{3½}$		
35.67	(?)	20	110.45	$a^2F_{2½}$—$z^2D^o_{2½}$		
33.74	—	2	119.06	$a^2P_{0½}$—$z^2P^o_{1½}$		
31.36	20	40	129.68	$b^2D_{2½}$—$z^4G^o_{3½}$		
19.10	20	30	184.57	$a^4P_{0½}$—$z^2P^o_{½}$		
14.99	—	3	203.04	$a^4P_{1½}$—$z^2D^o_{1½}$		
13.47	1	1	209.88	$b^2D_{2½}$—$z^2F^o_{2½}$		
4703.62	3	10	254.29	$b^4F_{4½}$—$y^4F^o_{3½}$		
4699.72	15	40	271.93	$b^4F_{2½}$—$z^2F^o_{1½}$		
82.68	—	8	349.34	$a^2H_{4½}$—$w^2F^o_{3½}$		
75.45	—	10	382.35	$b^2G_{3½}$—$z^2G^o_{4½}$		
64.14	100	150	434.20	$a^4P_{1½}$—$z^4D^o_{2½}$	(0.18, 0.51) 0.80, 1.12	(0.18, 0.56) 0.76, 1.04, 1.50, 1.88
59.22	4	4	456.83	$a^4P_{2½}$—$z^4G^o_{2½}$		
55.65	—	3	473.29			
40.14	8	20	545.06	$b^4F_{4½}$—$y^2F^o_{3½}$		
26.41	6 Zr?	6	609.00	$b^4F_{1½}$—$z^4P^o_{½}$		
22.71	30	100	626.29	$b^4F_{2½}$—$y^2D^o_{2½}$	(0.00 w) 1.06	(0.04, 0.10, 0.18) 0.90, 0.98, 1.04, 1.12, 1.18
13.74	10	50	668.34	$a^2H_{4½}$—$z^2H^o_{4½}$	(0.00) 1.04	(0.01, 0.03, 0.05, 0.07, 0.09) 0.96, 0.98, 1.00, 1.02, 1.04, 1.06, 1.08, 1.10, 1.12
4605.79	20	30	705.74	$a^2F_{2½}$—$z^4F^o_{3½}$		
4599.46	6	40	735.61	$b^2G_{4½}$—$z^2G^o_{4½}$		
86.25	4	10	798.22	$a^2F_{3½}$—$z^4D^o_{3½}$		
73.81	6	20	857.50	$b^2D_{2½}$—$z^4P^o_{1½}$		
70.70	2	30	872.38	$b^4P_{2½}$—$y^4P^o_{1½}$	(0.00) 1.45	(0.04, 0.10) 1.40, 1.48, 1.54, 1.62
63.81	—	8 h	905.40			
46.34	—	2	21989.57	$x^2D^o_{1½}$—5		
41.31	10	20	22013.93	$b^2D_{1½}$—$z^2P^o_{1½}$		
39.76	3	3	021.44	$a^4P_{1½}$—$z^4G^o_{2½}$		
35.38	6	30	042.71	$b^4F_{3½}$—$y^4F^o_{3½}$		
33.18	30	40	053.41	$a^2F_{2½}$—$z^2D^o_{1½}$	(0.00 w) 1.13 A?	(0.07, 0.21) 0.77, 0.91, 1.05, 1.19
24.74	3	30	094.54	$a^2H_{4½}$—$y^2G^o_{3½}$		
4519.02	—	10 h	122.51			
4490.60	2	20	262.51	$b^4F_{3½}$—$y^2F^o_{2½}$	(0.00 W) 1.69 h	(0.14, 0.42, 0.70) 0.53, 0 81, 1.09, 1.37, 1.65, 1.93
86.65	1	20	282.11	$c^2D_{2½}$—$w^2D_{2½}$	(0.00 w) 1.18	(0.03, 0.09, 0.15) 1.06, 1.12, 1.18, 1.24, 1.30
86.14	20	30	284.65	$a^2F_{2½}$—$z^4D^o_{2½}$		
83.29	—	5	298.81	$c^2D_{2½}$—$x^2P^o_{1½}$		
66.41	6	30	383.09	$b^4F_{2½}$—$y^4F^o_{1½}$	(0.00 W) 1.69	(0.22, 0.66) 0.35, 0.79, 1.23, 1.67
52.70	—	10	452.00	$b^2G_{3½}$—$x^2F^o_{2½}$	(0.00) 0.91	(0.00) 0.92
43.07	15	20	500.66			
26.18	3	9	586.52	$b^4P_{2½}$—$w^2D^o_{1½}$		
22.76	20	150	603.98	$a^2H_{5½}$—$z^2H^o_{4½}$	(0.00 w) 1.28 A?	(0.04, 0.10, 0.18, 0.24, 0.32) 0.78, 0.86, 0.92, 1.00, 1.06, 1.14, 1.20, 1.28, 1.34, 1.42
4417.37	40	100	631.57	$a^2P_{0½}$—$y^2D^o_{1½}$	(0.00) 0.78	(0.03) 0.77, 0.83
4397.15	—	3 h	735.64			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
85.52	—	5	795.93	$a^2G_{3\frac{1}{2}}$—$z^4P^o_{2\frac{1}{2}}$		
70.95	60	100	871.92	$a^2F_{2\frac{1}{2}}$—$z^4G^o_{2\frac{1}{2}}$	(0.00) 0.98	(0.01, 0.03, 0.05) 0.95, 0.97, 0.99, 1.01, 1.03
67.90	30	40	887.89	$a^4P_{2\frac{1}{2}}$—$z^2P^o_{1\frac{1}{2}}$	(0.00) 1.50	(0.06, 0.16) 1.26, 1.36, 1.48, 1.58
65.73	—	5	899.26			
50.52	30	150	22979.32	$b^4F_{4\frac{1}{2}}$—$y^4F^o_{4\frac{1}{2}}$	(0.34) 1.28 B	(0.04, 0.12, 0.20, 0.28, 0.36) 0.95, 1.03, 1.11, 1.19, 1.27, 1.35, 1.43, 1.51, 1.59
36.66	40	200	23052.76	$b^4F_{3\frac{1}{2}}$—$y^2F^o_{3\frac{1}{2}}$	(0.26) 1.19	(0.04, 0.10, 0.18, 0.24) 0.98, 1.06, 1.12, 1.20, 1.26, 1.34, 1.40
35.15	5	5	060.79	$a^4F_{3\frac{1}{2}}$—$z^4F^o_{4\frac{1}{2}}$		
34.65	10	30	063.45	$b^4F_{4\frac{1}{2}}$—$z^4G^o_{5\frac{1}{2}}$	(0.00) 1.16	(0.02, 0.06, 0.10, 0.14, 0.18) 1.09, 1.13, 1.17, 1.21, 1.25, 1.29, 1.33, 1.37, 1.41, 1.45
27.55	?	4	101.29	$a^2F_{3\frac{1}{2}}$—$z^4F^o_{4\frac{1}{2}}$		
21.36	2	30	134.38	$b^4P_{1\frac{1}{2}}$—$y^4P^o_{1\frac{1}{2}}$	(0.00 w) 1.70	(0.09, 0.27) 1.49, 1.67, 1.85
20.69	15	40	137.97	$b^2D_{2\frac{1}{2}}$—$z^4P^o_{2\frac{1}{2}}$	(0.35) 1.37 B w	(0.08, 0.24, 0.40) 1.05, 1.21, 1.37, 1.53, 1.69
4319.51	1	8	144.29	$a^2P_{0\frac{1}{2}}$—$z^4P^o_{0\frac{1}{2}}$		
4272.85	20	60	397.02	$a^4P_{2\frac{1}{2}}$—$z^4D^o_{3\frac{1}{2}}$	(0.00) 1.36	(0.02, 0.04, 0.08) 1.32, 1.34, 1.38, 1.40, 1.44, 1.46
69.67	10	20	414.45	$a^2F_{3\frac{1}{2}}$—$z^4G^o_{3\frac{1}{2}}$	(0.00) 1.00?	(0.02, 0.08, 0.12, 0.18) 0.94, 0.98, 1.04, 1.08, 1.14, 1.18, 1.24
68.10	—	5	423.06	$b^4P_{0\frac{1}{2}}$—$y^4P^o_{1\frac{1}{2}}$		
62.72	4	10	452.62	$a^4P_{1\frac{1}{2}}$—$z^2P^o_{1\frac{1}{2}}$		
52.61	?	1	508.38	$z^2G^o_{3\frac{1}{2}}$—3		
49.33	10	30	526.52	$b^2D_{1\frac{1}{2}}$—$y^2D^o_{1\frac{1}{2}}$	(0.37) 0.86 B	(0.12, 0.34) 0.68, 0.92, 1.14
45.84	8	20	545.86	$b^4F_{2\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$	(0.12) 0.98	(0.02, 0.04, 0.08) 0.94, 0.96, 1.00, 1.02, 1.06
41.93	1	7	567.56	$c^2D_{2\frac{1}{2}}$—$w^2P^o_{1\frac{1}{2}}$		
32.43	30	60	620.46	$b^4F_{1\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$	(0.14) 0.52	(0.06, 0.16) 0.40, 0.52, 0.62
31.61	—	2 Zr?	625.04	$b^4P_{1\frac{1}{2}}$—$x^2F^o_{2\frac{1}{2}}$		
18.84	(?)	1	696.55	$a^2G_{3\frac{1}{2}}$—$z^2F^o_{3\frac{1}{2}}$		
07.39	—	2	761.03	$a^2H_{4\frac{1}{2}}$—$y^2G^o_{4\frac{1}{2}}$		
06.59	30	80	765.55	$b^4F_{2\frac{1}{2}}$—$y^2F^o_{2\frac{1}{2}}$	(0.00) 1.02	(0.03, 0.09, 0.15) 0.86, 0.92, 0.98, 1.04, 1.10
4201.76	(?)	1	792.87	$b^4P_{2\frac{1}{2}}$—$x^2F^o_{3\frac{1}{2}}$		
4187.68	5	8	872.87	$b^4F_{1\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$		
79.55	1	10	919.30	$b^2F_{2\frac{1}{2}}$—$u^2D^o_{1\frac{1}{2}}$	(0.00) 0.92	
77.50	10	20	931.04	$a^2P_{1\frac{1}{2}}$—$y^2D^o_{2\frac{1}{2}}$	(0.00) 1.06	(0.02, 0.06) 1.02, 1.06, 1.10 1.14
70.41	2	2	971.72	$a^2P_{0\frac{1}{2}}$—$z^4P^o_{1\frac{1}{2}}$		
66.64	—	3	23993.41	$b^2P_{1\frac{1}{2}}$—$u^2D^o_{1\frac{1}{2}}$		
63.43	1	5	24011.91	$b^4F_{4\frac{1}{2}}$—$z^2G^o_{3\frac{1}{2}}$		
62.40	10	50	017.85	$a^2G_{4\frac{1}{2}}$—$z^2F^o_{3\frac{1}{2}}$	(0.00) 1.13	(0.00, 0.01, 0.02, 0.03) 1.09, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16
58.90	5	30	038.07	$b^2D_{2\frac{1}{2}}$—$z^2F^o_{3\frac{1}{2}}$	(0.00 w) 0.86 h	(0.08, 0.26, 0.42) 0.70, 0.86, 1.04, 1.20, 1.38, 1.54
56.74	(?)	4	050.56	$a^2G_{3\frac{1}{2}}$—$y^2D^o_{2\frac{1}{2}}$		
41.84	(?)	5	137.08	$b^4P_{0\frac{1}{2}}$—$w^2D^o_{1\frac{1}{2}}$		
40.21	(?)	2	146.58	$b^4F_{1\frac{1}{2}}$—$y^2P^o_{0\frac{1}{2}}$		
38.70	(?)	3	155.39	$b^4P_{2\frac{1}{2}}$—$w^2D^o_{2\frac{1}{2}}$		
27.80	10	40	219.17	$b^2D_{1\frac{1}{2}}$—$z^2F^o_{2\frac{1}{2}}$	(0.00 w) 0.72 A[1]	(0.07, 0.21) 0.68, 0.82, 0.96, 1.00
25.10	(?)	5	235.02	$b^2G_{4\frac{1}{2}}$—$x^2F^o_{3\frac{1}{2}}$		
23.54	1	10	244.19	$b^2G_{3\frac{1}{2}}$—$w^2D^o_{2\frac{1}{2}}$		
4113.58	15	20	302.89	$a^2F_{2\frac{1}{2}}$—$z^2P^o_{1\frac{1}{2}}$	(0.18, 0.54) 0.44, 0.79, 1.14	(0.16, 0.50) 0.48, 0.82, 1.14, 1.48, 1.80
4097.21	3?	8	399.99	$a^4P_{2\frac{1}{2}}$—$y^2D^o_{1\frac{1}{2}}$		
93.16	120	150	424.13	$a^4F_{1\frac{1}{2}}$—$z^4F^o_{1\frac{1}{2}}$	(0.08) 0.47	(0.04, 0.10) 0.42, 0.48, 0.56
82.67	—	1	486.89	$b^4F_{3\frac{1}{2}}$—$y^4F^o_{4\frac{1}{2}}$		
80.44	30	60	500.27	$a^4F_{2\frac{1}{2}}$—$z^4F^o_{2\frac{1}{2}}$	(0.00) 1.07	(0.01, 0.03, 0.05) 1.03, 1.05, 1.07, 1.09, 1.11
71.22	3	6	555.75	$b^4F_{2\frac{1}{2}}$—$y^2F^o_{3\frac{1}{2}}$		
50.67	2	7	680.33	$a^2G_{3\frac{1}{2}}$—$z^4G^o_{4\frac{1}{2}}$	(0.00 w) 1.69 h	(0.12, 0.38, 0.62, 0.88) 0.30, 0.54, 0.80, 1.04, 1.30, 1.54, 1.80, 2.04
49.44	4	10	687.82	$a^2P_{1\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$	(0.86) 0.31, 0.86, 1.39	(0.28, 0.82) 0.30, 0.84, 1.40
48.46	(?)	3	693.80	$a^2H_{4\frac{1}{2}}$—$z^2H^o_{5\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
47.96	4	50	696.85	$a^2H_{5\frac{1}{2}}$—$y^2G^o_{4\frac{1}{2}}$	(0.00) 1.16	(0.01, 0.03, 0.05, 0.07, 0.09) 1.01, 1.03, 1.05, 1.07, 1.09, 1.11, 1.13, 1.15, 1.17, 1.19
33.88	1	6	783.05	$b^4F_{1\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$	(0.26, 0.80) 1.30, 1.84	(0.26, 0.78) 0.20, 0.72, 1.24, 1.76
29.16	4	10	812.08	$a^2F_{2\frac{1}{2}}$—$z^4D^o_{3\frac{1}{2}}$	(0.21, 0.61) 2.39	(0.20, 0.62, 1.02) 0.36, 0.78, 1.20, 1.60, 2.00, 2.42
20.25	5?	5	867.07	$b^2D_{1\frac{1}{2}}$—$z^4P^o_{1\frac{1}{2}}$		
08.46	2?	8	940.21	$a^2P_{1\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$	(0.14) 1.15	(0.06, 0.18) 1.06, 1.18, 1.30
4007.36	2?	10	24947.06	$b^4P_{2\frac{1}{2}}$—$x^4P^o_{1\frac{1}{2}}$	(0.00) 1.58	(0.04, 0.14) 1.38, 1.46, 1.56, 1.64
3998.51	1?	6 d	25002.27	$a^2G_{4\frac{1}{2}}$—$z^4G^o_{4\frac{1}{2}}$	(0.24) 1.15	(0.02, 0.06, 0.10, 0.14, 0.18) 0.99, 1.03, 1.07, 1.11, 1.15, 1.19, 1.23, 1.27, 1.31
96.80	1?	5	012.97	$a^4P_{2\frac{1}{2}}$—$z^4G^o_{3\frac{1}{2}}$		
84.85	1	5	087.98	$b^2G_{3\frac{1}{2}}$—$z^2H^o_{4\frac{1}{2}}$	(0.18 h) 1.34 h	(0.06, 0.16, 0.28, 0.38) 0.64, 0.76, 0.86, 0.98, 1.08, 1.20, 1.30, 1.42
84.03	3	8	093.14	$a^4P_{2\frac{1}{2}}$—$z^2F^o_{2\frac{1}{2}}$	(1.40) 1.20	(0.26, 0.80, 1.32) 0.10, 0.62, 1.16, 1.68, 2.22
79.40	4	40	122.34	$b^2G_{4\frac{1}{2}}$—$w^2F^o_{3\frac{1}{2}}$	(0.00 w) 0.62 A[1]	(0.06, 0.18, 0.30, 0.42) 0.64, 0.76, 0.88, 1.00, 1.12, 1.24, 1.36, 1.48
75.15	—	4	149.26	$b^2D_{2\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$		
64.96	5	15	213.83	$a^2P_{1\frac{1}{2}}$—$y^2P^o_{0\frac{1}{2}}$	(0.29) 0.86, 1.42	(0.28) 0.84, 1.40
46.00	—	7 h	334.97	$b^2F_{3\frac{1}{2}}$—$v^2F^o_{3\frac{1}{2}}$	(0.00 h) 1.28 h	
45.36	—	10 h	339.08	$c^2D_{2\frac{1}{2}}$—$v^2D^o_{2\frac{1}{2}}$	(0.00 h) 1.24 h	(0.09, 0.27, 0.45) 0.88, 1.06, 1.24, 1.42, 1.60
35.64	7	20	401.66	$b^2D_{2\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$	(0.00) 1.33	(0.02, 0.08) 1.22, 1.26, 1.32, 1.36
33.65	30	40	414.51	$a^4F_{4\frac{1}{2}}$—$z^4F^o_{3\frac{1}{2}}$	(0.00 w) 1.47	(0.04, 0.10, 0.18, 0.24), 1.08 1.16, 1.22, 1.30, 1.36, 1.44, 1.50, 1.58
33.18	—	1	417.55	$b^4P_{1\frac{1}{2}}$—$w^2D^o_{2\frac{1}{2}}$		
32.40	3	10	422.59	$a^2F_{3\frac{1}{2}}$—$z^4P^o_{2\frac{1}{2}}$		
31.96	—	1	425.44	$b^4P_{2\frac{1}{2}}$—$w^4D^o_{3\frac{1}{2}}$		
29.53	3 Zr	3	441.16	$b^2G_{4\frac{1}{2}}$—$z^2H^o_{3\frac{1}{2}}$		
23.91	15	40	477.60	$a^4P_{1\frac{1}{2}}$—$z^4P^o_{1\frac{1}{2}}$	(0.47) 1.22, 2.16	(0.47) 1.22, 2.16.
18.10	60	100	515.38	$a^4F_{1\frac{1}{2}}$—$z^4D^o_{0\frac{1}{2}}$	(0.00) 0.41	(0.04) 0.41, 0.49.
17.47	4	20	519.48	$b^4F_{3\frac{1}{2}}$—$z^2G^o_{3\frac{1}{2}}$	(0.63) 1.12 Bw	(0.10, 0.30, 0.50, 0.70) 0.53, 0.73, 0.93, 1.13, 1.33, 1.53, 1.73.
3900.64	2	20	629.59	$a^2H_{5\frac{1}{2}}$—$z^2H^o_{5\frac{1}{2}}$	(0.00) 1.08	(0.01, 0.03, 0.05, 0.07, 0.09, 0.11) 0.99, 1.01, 1.03, 1.05, 1.07, 1.09, 1.11, 1.13, 1.15, 1.17, 1.19.
3883.77	6	20	740.91	$a^4P_{2\frac{1}{2}}$—$z^4P^o_{1\frac{1}{2}}$	(0.00w) 1.18	(0.13, 0.39) 1.03, 1.29, 1.55, 1.81.
82.23	—	3 h	751.12	$a^2H_{4\frac{1}{2}}$—$y^2G^o_{3\frac{1}{2}}$		
80.82	30	40	760.48	$a^4F_{1\frac{1}{2}}$—$z^4F^o_{2\frac{1}{2}}$	(0.32, 0.95) 0.78, 1.42, 2.06	(0.32, 0.94) 0.14, 0.76, 1.40, 2.02.
77.11	5	40	785.12	$b^4F_{4\frac{1}{2}}$—$y^4D^o_{3\frac{1}{2}}$	(0.00) 1.26	(0.03, 0.09, 0.15, 0.21) 1.10, 1.16, 1.22, 1.28, 1.34, 1.40, 1.46, 1.52.
72.55	7	20	815.49	$a^2F_{2\frac{1}{2}}$—$y^2D^o_{1\frac{1}{2}}$	(0.00 w) 1.21 A[2]	(0.09, 0.27) 0.71, 0.89, 1.07, 1.25.
67.32	4	15	850.40	$a^2P_{1\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$	(0.00 w) 0.82 A[1]	(0.07, 0.21) 0.77, 0.91, 1.05, 1.19.
64.75	2	20	867.59	$b^2G_{4\frac{1}{2}}$—$y^2G^o_{3\frac{1}{2}}$	(0.00 w) 0.45 A[1]	(0.07, 0.21, 0.35, ') 0.57, 0.71, 0.85, 0.99, 1.13, 1.27, 1.41, 1.55.
49.52	7	25	25969.93	$a^2G_{3\frac{1}{2}}$—$y^4F^o_{3\frac{1}{2}}$	(0.00) 0.83	(0.03, 0.09, 0.15) 0.77, 0.83, 0.89, 0.95, 1.01, 1.07.
38.37	1	3	26045.36	$b^4P_{1\frac{1}{2}}$—$x^4P^o_{0\frac{1}{2}}$	(0.38) 1.31	(0.41) 0.41, 1.35.
23.53	1	4	146.45	$b^4P_{2\frac{1}{2}}$—$x^4D^o_{1\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
19.90	—	2 h	171.30			
17.20	6	20	189.81	$a^2G_{3½}$—$y^2F^o_{3½}$	(0.00) 0.87	(0.02, 0.04, 0.08) 0.84, 0.88, 0.90, 0.94, 0.96, 1.00.
10.59	2	10	235.24	$b^2G_{3½}$—$x^4D^o_{3½}$	(0.19, 0.58, 0.96) 0.00 Wus	(0.19, 0.57, 0.95)−0.03, +0.35, 0.73, 1.11, 1.49, 1.87.
06.07	6	40	266.39	$b^4F_{3½}$—$y^4D^o_{2½}$	(0.00 w) 1.04 A[1]	(0.05, 0.15, 0.25) 0.98, 1.08, 1.18, 1.28, 1.38, 1.48.
3300.39	40?	5	305.65	$a^4P_{1½}$—$z^4P^o_{1½}$	(0.00) 1.69	(0.00) 1.68, 1.70.
3799.51	—	3	311.74	$b^2D_{2½}$—$y^4F^o_{3½}$		
97.95	5	10	322.55	$a^2F_{3½}$—$z^2F^o_{3½}$	(0.00) 1.12	(0.00, 0.01, 0.02, 0.03) 1.08, 1.09, 1.10, 1.11, 1.12, 1.13, 1.14.
93.37	40	60	354.33	$a^2D_{2½}$—$z^4F^o_{2½}$	(0.22) 1.13	(0.05, 0.15, 0.25) 0.93, 1.03, 1.13, 1.23, 1.33.
82.78	4	8	428.11	$a^2F_{2½}$—$z^4G^o_{3½}$	(0.00) 1.18	(0.04, 0.12, 0.20) 0.86, 0.94, 1.02, 1.10, 1.18, 1.26.
80.09	3	7	446.91	$a^4P_{0½}$—$z^4P^o_{0½}$	(0.00) 2.62	(0.01) 2.62.
72.83	—	1	497.80	$b^4P_{0½}$—$x^4P^o_{1½}$		
71.36	3	8	508.13	$a^2F_{2½}$—$z^2F^o_{2½}$	(0.24) 0.96	(0.04, 0.14, 0.22) 0.76, 0.84, 0.94, 1.02, 1.12.
70.64	—	3	513.19	$b^4P_{2½}$—$x^4P^o_{2½}$		
66.92	10	50	539.37	$b^4F_{2½}$—$y^4D^o_{1½}$	(0.00 w) 0.85 A[1]	(0.08, 0.22) 0.78, 0.94, 1.08, 1.24.
62.51	2	25	570.48	$a^2H_{4½}$—$x^4D^o_{3½}$	(0.00 w) 0.81 A[1]	(0.04, 0.10, 0.18, 0.24) 0.80, 0.88, 0.94, 1.02 1.08, 1.16, 1.22, 1.30.
58.04	—	3	602.08	$b^2G_{3½}$—$x^4P^o_{2½}$		
47.48	3	7	677.04	$a^2F_{3½}$—$y^2D^o_{2½}$	(0.00) 1.10	(0,02, 0.04, 0.08) 1.04, 1.06, 1.10, 1.12, 1.16, 1.18.
45.78	—	1	689.15	$a^2G_{3½}$—$y^4F^o_{3½}$		
44.98	3	15	701.91	$b^4F_{4½}$—$z^2G^o_{4½}$	(0.64) 1.20 Bw	(0.08, 0.22, 0.38, 0.52, 0.68) 0.64, 0.78, 0.94, 1.08, 1.24, 1.38, 1.54, 1.68, 1.84.
37.88	5	15	745.56	$b^4F_{1½}$—$y^4D^o_{0½}$	(0.00) 0.44	(0.00) 0.46.
19.27	50	70	879.38	$a^4F_{2½}$—$z^4D^o_{1½}$	(0.00 w) 0.85 A[1]	(0.08, 0.24) 0.82, 0.98, 1.14, 1.30.
05.40	5	15	26979.99	$a^2G_{3½}$—$y^2F^o_{3½}$	(0.64) 1.01 Bw	(0.12, 0.36, 0.60, 0.84) 0.32, 0.56, 0.80, 1.04, 1.28, 1.52, 1.76.
02.36	—	2	27002.14	$b^2F_{3½}$—$v^2F^o_{3½}$		
3701.15	15	40	010.97	$a^2G_{4½}$—$y^4F^o_{3½}$	(0.00) 1.02 A[1]	(0.02, 0.08, 0.12, 0.18) 0.96, 1.00, 1.06, 1.10, 1.16, 1.20, 1.26, 1.30.
3699.72	10	25	021.41	$a^4P_{2½}$—$z^4P^o_{2½}$	(0.00) 1.42	(0.02, 0.04, 0.08) 1.38, 1.40, 1.44, 1.46, 1.50.
99.56	1?	3	022.58	$b^4F_{2½}$—$z^2G^o_{3½}$		
98.39	3	10	031.13	$b^2D_{2½}$—$y^4F^o_{3½}$	(0.00 w) 1.02 A[1]	(0.06, 0.16, 0.28) 0.90, 1.02, 1.12, 1.24, 1.34, 1.46.
81.39	2	4	155.95	$a^2F_{2½}$—$z^4P^o_{1½}$		
78.05	—	3	180.61	$b^2G_{3½}$—$y^2G^o_{4½}$		
66.79	—	2	264.08	$a^2P_{0½}$—$y^4F^o_{1½}$		
65.35	8	20	274.78	$a^4P_{0½}$—$z^4P^o_{1½}$	(0.48) 1.12, 2.08	(0.46) 1.22, 2.14.
61.73	—	2	301.75	$a^2G_{4½}$—$y^2F^o_{3½}$		
61.05	5	12	306.82	$a^2F_{3½}$—$z^4G^o_{4½}$	(0.00 w) 1.37 A[2]	(0.03, 0.09, 0.15, 0.21) 0.96, 1.02, 1.08, 1.14, 1.20, 1.26, 1.32, 1.38
59.02	2	4	321.97	$b^2D_{2½}$—$y^2F^o_{3½}$	(0.00 w) 1.02 h	(0.06, 0.20, 0.32) 0.84, 0.96, 1.10, 1.22, 1.36, 1.48
56.64	—	2	339.75	$b^2P_{1½}$—$u^2D^o_{2½}$		
48.35	4	6	401.87	$b^2D_{1½}$—$y^2D^o_{2½}$	(0.00) 1.14	(0.02, 0.08) 1.00, 1.06, 1.10, 1.16
47.48	—	2	408.41	$b^4P_{1½}$—$x^4D^o_{2½}$		
44.35	50	60	431.95	$a^4F_{3½}$—$z^4F^o_{3½}$	(0.00) 1.25	(0.04, 0.08, 0.10) 1.14, 1.18, 1.22, 1.24, 1.28, 1.30, 1.34
42.54	—	1	445.58	$y^4F^o_{1½}$—5		
33.19	2	4	516.21	$a^2P_{0½}$—$y^2P^o_{1½}$	(0.25) 1.50	(0.25) 0.99, 1.49

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
30.86	15?	2	533.86	$b^2G_{4\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$		
24.00	6	10	585.98	$a^4P_{1\frac{1}{2}}-z^4P^{\circ}_{2\frac{1}{2}}$	(0.11, 0.34) 1.14 A[1]	(0.12, 0.36) 1.09, 1.33, 1.57, 1.81
22.46	1	4	597.71	$b^4F_{1\frac{1}{2}}-z^2S^{\circ}_{0\frac{1}{2}}$	(0.62) 0.16	(0.61)− 0.15, +1.07
3600.07	1	4	769.34	$b^4F_{2\frac{1}{2}}-y^4D^{\circ}_{2\frac{1}{2}}$		
3599.16	—	3	776.36	$b^4F_{1\frac{1}{2}}-y^4D^{\circ}_{1\frac{1}{2}}$	(0.38, 1.12) 0.00, 0.80, 1.56	(0.35, 1.05) 0.11, 0.81, 1.51
97.42	5	10	789.80	$a^2P_{0\frac{1}{2}}-y^2P^{\circ}_{0\frac{1}{2}}$	(0.00) 0.66	(0.09) 0.65
94.42	—	2	812.99	$a^2P_{1\frac{1}{2}}-y^4D^{\circ}_{0\frac{1}{2}}$		
91.11	—	1	838.63	$b^4F_{2\frac{1}{2}}-z^2D^{\circ}_{1\frac{1}{2}}$		
80.46	1	3	27921.43	$a^4P_{2\frac{1}{2}}-z^2F^{\circ}_{3\frac{1}{2}}$		
69.03	50	80	28010.85	$a^4F_{3\frac{1}{2}}-z^4D^{\circ}_{2\frac{1}{2}}$	(0.00) 1.10	(0.04, 0.14, 0.22) 1.00, 1.10, 1.18, 1.28, 1.36, 1.46
61.65	70	80	068.89	$a^2D_{1\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	(0.13, 0.39) 0.37, 0.62, 0.88	(0.14, 0.42) 0.38, 0.66, 0.94
52.70	30	40	139.60	$a^4F_{1\frac{1}{2}}-z^4D^{\circ}_{1\frac{1}{2}}$	(0.40, 1.19) 0.00, 0.79, 1.59	(0.38, 1.16) 0.06, 0.84, 1.60
50.27	—	1	158.85	$b^2D_{1\frac{1}{2}}-y^4F^{\circ}_{1\frac{1}{2}}$		
44.78	—	2	202.47	$b^4F_{3\frac{1}{2}}-z^2G^{\circ}_{4\frac{1}{2}}$		
35.54	50	80	276.17	$a^4F_{2\frac{1}{2}}-z^2D^{\circ}_{2\frac{1}{2}}$	(0.00) 1.05	(0.00, 0.01, 0.02) 1.03, 1.04, 1.05, 1.06, 1.07
18.75	6	15	411.09	$b^2D_{1\frac{1}{2}}-y^2P^{\circ}_{1\frac{1}{2}}$	(0.26) 1.14	(0.10, 0.32) 0.92, 1.14, 1.34
18.38	—	3	414.08	$a^2G_{3\frac{1}{2}}-y^4F^{\circ}_{2\frac{1}{2}}$		
15.62	—	1	436.38	$a^2F_{2\frac{1}{2}}-z^4P^{\circ}_{2\frac{1}{2}}$		
11.88	1	4	466.66	$b^2G_{4\frac{1}{2}}-z^2H^{\circ}_{5\frac{1}{2}}$		
3505.22	50	150	520.75	$a^4F_{4\frac{1}{2}}-z^4D^{\circ}_{3\frac{1}{2}}$	(0.00) 1.22	(0.03, 0.09, 0.15, 0.21) 1.12, 1.18, 1.24, 1.30, 1.36, 1.42, 1.48, 1.54
3495.94	3	10	596.46	$a^2F_{3\frac{1}{2}}-y^4F^{\circ}_{2\frac{1}{2}}$	(0.00 w) 1.29 A[2]	(0.06, 0.18, 0.32) 0.78, 0.92, 1.04, 1.18, 1.30, 1.44
95.75	12	20	598.01	$a^4F_{3\frac{1}{2}}-z^4G^{\circ}_{2\frac{1}{2}}$	(0.11, 0.32, 0.54) 1.57, 1.80	(0.12, 0.34, 0.58) 0.66, 0.88, 1.12, 1.34, 1.58, 1.80
87.57	4	8	665.08	$a^2P_{1\frac{1}{2}}-z^2S^{\circ}_{0\frac{1}{2}}$	(0.25) 0.86, 1.35	(0.28) 0.84, 1.40
85.16	2	3	684.91	$b^2D_{1\frac{1}{2}}-y^2P^{\circ}_{0\frac{1}{2}}$		
79.29	30	40	733.30	$a^2D_{2\frac{1}{2}}-z^4D^{\circ}_{1\frac{1}{2}}$	(0.00) 1.14	(0.02, 0.06) 1.12, 1.16, 1.20, 1.24
78.98	8	30	735.86	$a^2G_{4\frac{1}{2}}-y^4F^{\circ}_{3\frac{1}{2}}$	(0.42) 1.20 Bw	(0.05, 0.15, 0.25, 0.35, 0.45) 0.78, 0.88, 0.98, 1.08, 1.18, 1.28, 1.38, 1.48, 1.58
75.85	—	2	761.74	$z^4D^{\circ}_{3\frac{1}{2}}-1$		
69.23	1	2	816.62	$a^2F^{3}_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$		
68.86	2	2	819.69	$a^2G_{4\frac{1}{2}}-z^4G^{\circ}_{5\frac{1}{2}}$		
65.92	1	2	844.14	$a^2P_{1\frac{1}{2}}-y^4D^{\circ}_{1\frac{1}{2}}$		
62.65	10	15	28871.37	$a^4P_{2\frac{1}{2}}-z^4F^{\circ}_{3\frac{1}{2}}$	(0.00 w) 1.75 A[2]	(0.10, 0.30, 0.50) 0.76, 0.96, 1.16, 1.36, 1.56, 1.76
43.42	—	1	29032.60	$a^4P_{2\frac{1}{2}}-y^4F^{\circ}_{1\frac{1}{2}}$		
38.24	10	15+Zr	076.34	$b^4F_{1\frac{1}{2}}-x^4D^{\circ}_{1\frac{1}{2}}$		
28.37	15	20	160.05	$a^2D_{1\frac{1}{2}}-z^4D^{\circ}_{0\frac{1}{2}}$	(0.12) 0.72, 0.96	(0.14) 0.67, 0.94
21.45	3	4	219.02	$a^4F_{2\frac{1}{2}}-z^2D^{\circ}_{1\frac{1}{2}}$		
13.74	3	8	285.01	$a^4P_{2\frac{1}{2}}-y^2P^{\circ}_{1\frac{1}{2}}$	(0.00 w) 1.62 A[2]	(0.09, 0.27) 1.15, 1.33, 1.51, 1.69
10.18	15	40	315.58	$a^2F_{3\frac{1}{2}}-y^4F^{\circ}_{3\frac{1}{2}}$	(0.24) 1.14 Bw	(0.04, 0.10, 0.18, 0.24) 0.94, 1.00, 1.08, 1.14, 1.22, 1.28, 1.36
3407.76	7	15	336.40	$a^2F_{2\frac{1}{2}}-z^2F^{\circ}_{3\frac{1}{2}}$	(0.00 w) 1.32 A[2]	(0.07, 0.21, 0.35) 0.77, 0.91, 1.05, 1.19, 1.33, 1.47
3399.80	100	150	405.09	$a^2D_{1\frac{1}{2}}-z^4F^{\circ}_{2\frac{1}{2}}$	(0.14, 0.41) 1.21, 1.48	(0.14, 0.42) 0.66, 0.94, 1.22 1.50
94.99	6	30	446.75	$a^2G_{3\frac{1}{2}}-z^2G^{\circ}_{3\frac{1}{2}}$	(0.23) 0.99	(0.06, 0.16, 0.28, 0.38) 0.64, 0.76, 0.86, 0.98, 1.08, 1.20, 130
94.58	10	25	450.30	$a^4F_{2\frac{1}{2}}-z^4D^{\circ}_{2\frac{1}{2}}$	(0.64) 1.16 B	(0.13, 0.39, 0.65) 0.67, 0.93. 1.19, 1.45, 1.71
89.83	40	70	491.57	$a^4F_{1\frac{1}{2}}-z^2P^{\circ}_{0\frac{1}{2}}$	(0.00) 0.49	(0.08) 0.37, 0.53
86.10	—	2	524.05	$b^2G_{4\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$		
85.22	—	2	531.73			
84.70	10	20	536.27	$a^4F_{1\frac{1}{2}}-z^2D^{\circ}_{2\frac{1}{2}}$	(0.29, 0.87) 0.80, 1.40, 2.00	(0.30, 0.90) 0.15, 0.75, 1.35, 1.95

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
84.14	5	10	541.15	$b^2D_{1½}-y^2F^o_{2½}$	(0.00) 1.01	(0.04, 0.12) 0.83, 0.91, 0.99, 1.07
76.68	1	4	606.42	$a^2F_{3½}-y^2F^o_{3½}$		
70.69	—	5	659.03	$b^2G_{3½}-v^2D^o_{2½}$		
67.09	1	2	690.74	$a^2F_{2½}-y^2D^o_{2½}$		
65.80	—	2	702.12			
58.30	3	8	768.45	$a^2G_{4½}-z^2G^o_{3½}$		
56.05	4	6+Zr	788.40	$b^2D_{2½}-z^2G^o_{3½}$		
52.06	40	80	823.86	$a^4F_{4½}-z^4F^o_{4½}$	(0.00) 1.34	(0.00, 0.01, 0.02, 0.03, 0.04) 1.29, 1,30, 1.31, 1.32, 1.33, 1.34, 1.35, 1.36,1.37
49.17	—	5	849.59	$a^4P_{1½}-y^2P^o_{1½}$		
33.49	—	2	29989.99	$b^2G_{3½}-x^4D^o_{3½}$		
28.21	15	20	30037.57	$a^4F_{2½}-z^4G^o_{2½}$	(0.00 w) 1.07	(0.03, 0.09, 0.15) 0.91, 0.97, 1.03, 1.09, 1.15
24.18	2	6	073.98	$a^2P_{1½}-y^4D^o_{2½}$		
23.35	4	20	081.50	$b^4F_{4½}-w^2F^o_{3½}$	(0.00 w) 1.74 A^2	(0.06, 0.20, 0.32, 0.46) 0.86, 0.98, 1.12, 1.24, 1.38, 1.50, 1.64, 1.76
18.74	1	1	123.28	$a^4P_{1½}-y^2P^o_{0½}$		
17.99	15	20	130.09	$a^2D_{2½}-z^2D^o_{2½}$	(0.29) 1.12	(0.06, 0.20, 0.32) 0.86, 0.98, 1.12, 1.24, 1.38
17.24	—	2	136.90	$a^4F_{4½}-z^4G^o_{3½}$		
14.03	—	2	166.09	$a^2P_{1½}-z^4S^o_{1½}$		
3310.85	2	6	195.06	$a^4P_{2½}-y^4F^o_{2½}$		
3294.68	—	3	343.25	$b^2G_{4½}-x^4D^o_{3½}$		
89.74	2	3	388.82	$a^2P^o_{0½}-y^4D^o_{0½}$		
83.39	3	6	447.58	$a^2F_{2½}-y^4F^o_{1½}$		
79.98	20?	20	479.24	$a^4F_{1½}-z^2D^o_{1½}$	(0.57) 0.28, 0.63, 0.98	(0.20, 0.58) 0.26, 0.64, 1.04
73.66	6?	6	538.08	$a^4F_{3½}-z^4D^o_{3½}$		
66.53	—	2	604.73	$b^2D_{2½}-x^2D^o_{1½}$		
56.15	—	1	702.29	$b^4F_{3½}-x^2F^o_{3½}$		
55.28	15	25	710.50	$a^4F_{1½}-z^4D^o_{2½}$	(0.45, 1.34) 0.93, 1.81, 2.70	(0.44, 1.30) 0.02, 0.88, 1.76, 2.62
53.70	30	80	725.41	$a^2D_{2½}-z^4F^o_{3½}$	(0.00) 1.38	(0.04, 0.12, 0.20) 1.06, 1.14, 1.22, 1.30, 1.38, 1.46.
50.07	—	1	759.73	$a^4P_{1½}-y^4F^o_{2½}$		
43.00	1	6	826.78	$b^4F_{4½}-y^2G^o_{3½}$	(0.00) 1.57	(0.06, 0.16, 0.28, 0.38) 0.92, 1.04, 1.14, 1.26, 1.36, 1.48, 1.58, 1.70
33.80	1	4	914.48	$a^4P_{2½}-y^4F^o_{3½}$		
27.00	2	4	979.6 2	$a^4P_{1½}-y^2F^o_{2½}$		
25.04	1	4	30998.45	$b^4F_{2½}-w^2D^o_{1½}$		
20.66	10	50	31040.60	$a^2F_{3½}-y^4F^o_{4½}$	(0.00 w) 1.55 A^2	(0.06, 0.18, 0.30, 0.42) 0.81, 0.93, 1.05, 1.17, 1.29, 1.41, 1.53, 1.65
18.20	2	8	064.33	$b^4F_{3½}-w^2D^o_{2½}$		
17.30	20	25	073.02	$a^2D_{2½}-z^2D^o_{1½}$	(0.16, 0.48) 1.66 A^2	(0.17, 0.51) 0.67, 1.01, 1.35, 1.69
15.29	—	1	092.44	$a^4P_{0½}-y^2P^o_{0½}$		
06.77	1	4	175.05	$a^2P_{1½}-x^2D^o_{2½}$	(0.00) 1.36	(0.07, 0.21) 1.05, 1.19, 1.33, 1.47
03.67	3	10	205.21	$a^4P_{2½}-y^2F^o_{3½}$	(0.00 w) 0.76	(0.13, 0.39, 0.65) 0.51, 0.77, 1.03, 1.29, 1.55, 1.81
3202.16	1	4	219.93	$a^2G_{3½}-y^4D^o_{3½}$		
3199.99	6	30	241.10	$a^2P_{0½}-z^2S^o_{0½}$	(0.48) 1.22	(0.47) 1.21
98.33	—	2	257.31	$y^2F^o_{2½}-9$		
95.63	4	8	283.72	$b^2D_{1½}-y^4D^o_{0½}$	(0.26) 1.33	(0.28) 0.75, 1.31
94.47	1	5	295.08	$a^2G_{3½}-x^2D^o_{2½}$		
94.19	50	100	297.82	$a^4F_{1½}-z^4G^o_{2½}$	(0.27, 0.81) 0.76, 1.30, 1.83	(0.28, 0.82) 0.18, 0.72, 1.28, 1.82
93.53	30	40	304.29	$a^2D_{2½}-z^4D^o_{3½}$	(0.35) 1.24 B w	(0.07, 0.21, 0.35) 0.97, 1.11, 1.25, 1.39, 1.53
85.32	—	3	384.98	$z^2F^o_{2½}-5$		
83.67	—	1	401.24	$y^4F^o_{3½}-10$		
81.76	1	3	420.09	$a^2P_{0½}-y^4D^o_{1½}$		
76.85	40	50	468.65	$a^4F_{2½}-z^2P^o_{1½}$	(0.00 w) 0.74 A^1	(0.12, 0.38) 0.68, 0.94, 1.18, 1.44
67.46	1	3	561.94	$b^2D_{2½}-y^4D^o_{3½}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
62.61	5?	40	610.33	$a^2F_{2½}$—$y^4F^o_{2½}$	(0.00) 0.96	(0.00) 0.98
59.93	—	2	637.14	$b^2D_{2½}$—$x^2D^o_{2½}$		
45.32	20	25	784.09	$a^2D_{1½}$—$z^4D^o_{1½}$		
40.77	7	15	830.14	$a^2F_{2½}$—$y^2F^o_{2½}$	(0.00) 0.99	(0.02, 0.04, **0.08**) 0.90, 0.94, **0.96**, 1.00, 1.02
39.67	10	15	841.29	$a^4F_{3½}$—$z^4F^o_{4½}$	(0.00 w) 1.50	(**0.06**, 0.16, 0.28, 0.38) 0.96, 1.06, 1.18, 1.28, 1.40, 1.50, 1.62, **1.72**
34.72	70	150	891.56	$a^2D_{2½}$—$z^4G^o_{2½}$	(0.44) 1.09 B w	(0.09, 0.27, **0.45**) 0.73, 0.91, **1.09**, 1.27, 1.45
33.50	1	4 Zr?	903.98	$y^2D^o_{2½}$—6		
33.10	1	4	908.05	$b^4F_{3½}$—$z^2H^o_{4½}$		
26.27	3	6	31977.76	$a^4F_{2½}$—$z^4D^o_{3½}$		
16.95	3	8	32073.37	$a^2F_{3½}$—$z^2G^o_{3½}$	(0.00) 1.10	(0.04, 0.12, 0.20, **0.28**) 0.83, 0.91, 0.99, **1.07**, 1.15, 1.23 ,1.31
11.49	—	2	129.66	$a^2G_{3½}$—$z^2G^o_{4½}$		
10.87	10	40	136.06	$b^2D_{1½}$—$z^2S^o_{0½}$	(0.32) 0.72	(0.32) **0.70**, 1.36
09.11	50	150	154.25	$a^4F_{3½}$—$z^4G^o_{3½}$	(0.59) 1.14 B w	(0.08, 0.26, 0.42, **0.60**) 0.64, 0.80, 0.98, **1.14**, 1.32, 1.48, 1.66
07.83	—	2	167.49	$z^4G^o_{3½}$—3		
3101.39	40	100	234.28	$a^4F_{3½}$—$z^2F^o_{2½}$	(**0.14**, 0.43, 0.72) 2.15 A^2	(**0.17**, 0.51, 0.85) 0.38, 0.72, 1.06, 1.40, 1.74, **2.08**
3099.13	—	3	257.79	$z^2F^o_{3½}$—6		
92.26	6	20	329.45	$a^2F_{2½}$—$y^4F^o_{3½}$	(0.00 w) 1.70 A^2	(**0.10**, 0.30, 0.50) 0.68, 0.88, 1.08, 1.28, 1.48, **1.68**
91.79	1	5	334.37	$b^4F_{3½}$—$y^2G^o_{3½}$		
83.65	1	3	419.72			
80.64	20	100	451.39	$a^2G^o_{3½}$—$z^2G^o_{1½}$	(0.00) 1.15	(0.02, 0.04, 0.08, 0.10, **0.14**) 1.02, 1.06, 1.08, 1.12, **1.14**, 1.18, 1.20, 1.24, 1.26
76.70	1	4	492.95	$b^4F_{4½}$—$y^2G^o_{4½}$		
70.00	—	4	563.86	$a^2H_{4½}$—$z^2F^o_{3½}$		
69.66	—	2 Cb?	567.46	$b^4F_{2½}$—$w^2D^o_{2½}$		
66.53	—	3	600.70	$z^4D^o_{3½}$—4		
64.68	7	20	620.38	$a^2F_{2½}$—$y^2F^o_{3½}$	(0.00 w) 1.46 A^2	(**0.09**, 0.27, 0.45) 0.71, 0.89, 1.07, 1.25, 1.43, **1.61**
64.38	—	5	623.58	$y^2F^o_{3½}$—14		
55.43	4	9	719.13	$a^2P_{0½}$—$x^2D^o_{1½}$	(0.00 w) 1.33	(0.24) 0.98, **1.44**
54.52	6	15	728.88	$a^4F_{1½}$—$z^2P^o_{1½}$		
46.03	5	20	820.10	$a^2F_{3½}$—$y^4D^o_{3½}$	(0.00 w) 0.75	(**0.11**, 0.33, 0.55) **0.56**, 0.78, 1.00, 1.22, 1.44, 1.66
35.28	—	3	936.33	$z^2P^o_{1½}$—2		
31.16	60	120	32981.10	$a^4F_{2½}$—$y^2D^o_{1½}$	(**0.13**, 0.38) 1.42 A^2	(**0.13**, 0.39) 0.67, 0.93, **1.19**, **1.45**
25.29	10	20	33045.09	$a^4F_{4½}$—$z^2F^o_{3½}$	(0.00 w) 1.96 A^2	(**0.10**, 0.32, 0.52, 0.64) 0.60, 0.80, 1.02, 1.22, 1.44, 1.64 1.86, **2.06**
24.78	3	15	050.66	$b^2D_{2½}$—$y^4P^o_{1½}$	(0.00 w) 0.89 A^1	(**0.14**, 0.44) **0.86**, 1.14, 1.44 1.72
24.35	—	2	055.36	$b^4F_{3½}$—$x^4D^o_{2½}$		
22.11	1	4	079.86	$a^2P_{1½}$—$x^2F^o_{2½}$		
16.94	5	6	136.54	$a^2D_{1½}$—$z^2P^o_{0½}$		
14.98	—	3	158.09	$z^4P^o_{2½}$—6		
12.90	50	100	180.98	$a^2D_{1½}$—$z^2D^o_{2½}$	(0.00 w) 1.37 A^2	(**0.12**, 0.38) 0.68, 0.92, 1.18, **1.42**
12.19	—	4	188.79	$a^4P_{2½}$—$y^4D^o_{1½}$		
11.24	3	20	199.27	$a^2G_{3½}$—$x^2F^o_{3½}$	(0.00) 1.06	(0.00) 0.92
04.77	—	3	270.75			
01.85	—	4	303.11	$a^2P_{1½}$—$w^2D^o_{1½}$		
3000.09	25	40	322.65	$a^2D_{2½}$—$z^2P^o_{1½}$	(0.00 w) 1.04 A^1	(**0.06**, 0.20) **0.98**, 1.12, 1.24, **1.38**
2996.76	—	3	359.67	$b^4F_{2½}$—$x^4P^o_{1½}$		
93.45	—	2	396.56			
90.83	1	7	425.81	$b^4F_{4½}$—$z^2H^o_{5½}$		
84.38	—	3	498.05	$y^4F^o_{1½}$—11		
80.21	1	4	544.92	$b^2D_{1½}$—$y^4D^o_{2½}$		
77.59	6	25	574.44	$a^4P_{1½}$—$z^2S^o_{0½}$	(0.00) 1.68	(0.00) 1.68, **1.70**
77.13	—	5	579.62			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
75.89	70	150	593.62	$a^4F_{2\frac{1}{2}}$—$z^4G^0_{3\frac{1}{2}}$	(0.00) 1.04	(0.00) 1.06
74.09	1	6	613.95	$b^2D_{1\frac{1}{2}}$—$x^2D^0_{1\frac{1}{2}}$		
70.60	—	2	653.44			
68.94	5	15	672.25	$a^4P_{2\frac{1}{2}}$—$z^2G^0_{3\frac{1}{2}}$		
68.82	60	120	673.61	$a^4F_{2\frac{1}{2}}$—$z^2F^0_{3\frac{1}{2}}$	(0.43) 0.97 Bw	(0.08, 0.26, 0.42) 0.64, 0.80, 0.98, 1.14, 1.32
67.24	10	30	691.54	$a^4P_{0\frac{1}{2}}$—$y^4D^0_{0\frac{1}{2}}$	(1.09) 1.55	(1.07) 1.54
63.75	—	2	731.21			
61.80	6	40	753.42	$a^4P_{1\frac{1}{2}}$—$y^4D^0_{1\frac{1}{2}}$	(0.67) 1.44 Bw	(0.26, 0.80) 0.90, 1.42, 1.96
60.83	2	15	764.48	$b^2D_{2\frac{1}{2}}$—$w^2D^0_{1\frac{1}{2}}$	(0.00 w) 1.50 A[2]	(0.10, 0.28) 1.00, 1.20, 1.38, 1.58
59.17	—	4	783.42	$z^4D^0_{3\frac{1}{2}}$—3		
56.01	—	1	819.53	$b^4F_{1\frac{1}{2}}$—$x^4D^0_{1\frac{1}{2}}$		
53.65	2	4	846.55	$a^2F_{3\frac{1}{2}}$—$y^4D^0_{3\frac{1}{2}}$		
52.53	—	1	859.39	$z^4D^0_{1\frac{1}{2}}$—1		
49.62	—	6	892.79	$z^2G^0_{3\frac{1}{2}}$—17		
47.14	4	12	33921.31	$a^2F_{3\frac{1}{2}}$—$x^2D^0_{2\frac{1}{2}}$	(0.00 w) 0.86	(0.08, 0.22, 0.38) 0.74, 0.88, 1.04, 1.18, 1.34, 1.48
40.26	—	2	34000.68	$b^4F_{3\frac{1}{2}}$—$y^2G^0_{4\frac{1}{2}}$		
37.79	50	120	029.27	$a^4F_{4\frac{1}{2}}$—$z^4G^0_{4\frac{1}{2}}$	(0.60) 1.24 Bw	(0.08, 0.24, 0.40, 0.56, 0.72) 0.61, 0.77, 0.93, 1.09, 1.25, 1.41, 1.57, 1.73, 1.89
30.60	—	7 h	112.75			
29.63	70	80	124.05	$a^2D_{1\frac{1}{2}}$—$z^2D^0_{1\frac{1}{2}}$	(0.00) 0.82	(0.02, 0.06) 0.78, 0.82, 0.86
26.33	2	4	162.53	$a^4F_{3\frac{1}{2}}$—$z^4P^0_{2\frac{1}{2}}$		
26.06	—	5	165.68			
19.59	40	90	241.39	$a^4F_{1\frac{1}{2}}$—$y^2D^0_{1\frac{1}{2}}$	(0.54) 0.30, 0.60, 0.90	(0.18, 0.52) 0.28, 0.62, 0.98
17.51	3	12	265.80	$a^2P_{1\frac{1}{2}}$—$x^4D^0_{0\frac{1}{2}}$		
13.21	1	7	316.37	$b^2G_{3\frac{1}{2}}$—$v^2F^0_{3\frac{1}{2}}$		
12.79	1	3	321.32	$a^4F_{2\frac{1}{2}}$—$z^4P^0_{1\frac{1}{2}}$		
09.91	20	30	355.29	$a^2D_{1\frac{1}{2}}$—$z^4D^0_{2\frac{1}{2}}$	(0.30) 2.02	(0.26, 0.78) 0.54, 1.06, 1.58, 2.10
08.86	1	15	367.69	$z^4G^0_{2\frac{1}{2}}$—2		
06.63	—	1	394.05	$z^2F^0_{3\frac{1}{2}}$—10		
04.51	?	10	419.16	$a^4P_{2\frac{1}{2}}$—$y^4D^0_{2\frac{1}{2}}$		
2903.57	—	3	430.30			
2898.71	15	60	488.02	$a^4P_{2\frac{1}{2}}$—$x^2D^0_{1\frac{1}{2}}$	(0.00w) 1.73A[2]	(0.10, 0.32) 1.10, 1.32, 1.52, 1.74
94.01	1	4	544.03	$a^4P_{0\frac{1}{2}}$—$z^2S^0_{0\frac{1}{2}}$		
92.31	—	4	564.33			
89.01	1	6	603.81	$a^2F_{2\frac{1}{2}}$—$y^4D^0_{1\frac{1}{2}}$		
86.91	—	2	628.98	$a^2G_{3\frac{1}{2}}$—$x^2F^0_{3\frac{1}{2}}$		
85.47	4	20	646.26	$b^2D_{1\frac{1}{2}}$—$x^2D^0_{2\frac{1}{2}}$	(0.00) 1.44	(0.12, 0.34) 0.92, 1.14, 1.38, 1.60
80.24	—	2	709.17			
79.75	—	6	715.08			
79.12	5	20	722.67	$a^4P^0_{0\frac{1}{2}}$—$y^4D^0_{1\frac{1}{2}}$		
76.33	10	100	756.35	$a^2F_{3\frac{1}{2}}$—$z^2G^0_{4\frac{1}{2}}$	(0.00) 1.29	(0.02, 0.08, 0.12, 0.18) 0.98, 1.04, 1.08, 1.14, 1.18, 1.24, 1.28, 1.34
70.78	—	2	823.54	$y^2D^0_{2\frac{1}{2}}$—12		
69.82	15	20	835.19	$a^2D_{2\frac{1}{2}}$—$y^2D^0_{2\frac{1}{2}}$		
65.57	—	4	886.85	$a^2P_{1\frac{1}{2}}$—$z^4D^0_{1\frac{1}{2}}$		
61.69	80	160	934.15	$a^4F_{1\frac{1}{2}}$—$z^2F^0_{2\frac{1}{2}}$	(0.22, 0.67) 0.63, 1.09, 1.54	(0.22, 0.66) 0.23, 0.67, 1.11, 1.55
61.01	60	100	942.45	$a^2D_{1\frac{1}{2}}$—$z^4G^0_{2\frac{1}{2}}$	(0.00 w) 1.20A[2]	(0.10, 0.30) 0.70, 0.90, 1.10, 1.30
60.32	2	15	950.88	$a^2G_{4\frac{1}{2}}$—$x^2F^0_{3\frac{1}{2}}$	(0.00) 1.06	(0.02, 0.06, 0.10, 0.14) 0.99, 1.03, 1.07, 1.11, 1.15, 1.19, 1.23, 1.27
58.68	—	3	970.93	$b^2D_{2\frac{1}{2}}$—$x^2F^0_{3\frac{1}{2}}$		
57.65	3	20	983.54	$a^4P_{1\frac{1}{2}}$—$y^4D^0_{2\frac{1}{2}}$		
56.99	—	4	34991.62	$a^2G_{3\frac{1}{2}}$—$w^2D^0_{2\frac{1}{2}}$		
52.02	10	40	35052.59	$a^4P_{1\frac{1}{2}}$—$x^2D^0_{1\frac{1}{2}}$	(0.75) 1.49	(0.24, 0.72) 0.97, 1.45, 1.94
51.22	20	60	062.43	$a^4F_{3\frac{1}{2}}$—$z^2F^0_{3\frac{1}{2}}$	(0.39) 1.18B	(0.06, 0.16, 0.28, 0.38) 0.84, 0.96, 1.06, 1.18, 1.28, 1.40, 1.50
50.15	4	15	075.59	$a^4P_{1\frac{1}{2}}$—$z^4S^0_{1\frac{1}{2}}$		
49.21	20	100	087.16	$a^2F_{3\frac{1}{2}}$—$z^2G^0_{3\frac{1}{2}}$	(0.00) 1.14	(0.02, 0.08, 0.12) 0.90, 0.96, 1.00, 1.06, 1.10, 1.16
47.70	—	2	105.76			
47.08	—	2	113.41	$y^2F^0_{3\frac{1}{2}}$—16		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
46.40	—	6	121.80			
45.15	—	3	137.23			
41.95	—	10 hl	176.79			
41.20	—	1	186.07	$z^2D^{\circ}_{1\frac{1}{2}}$—2		
38.79	—	2	215.94			
35.18	—	5 h	260.78	$y^2D^{\circ}_{1\frac{1}{2}}$—8		
32.59	—	2	293.02			
29.33	4	20	333.68	$b^2D_{2\frac{1}{2}}$—$w^2D^{\circ}_{2\frac{1}{2}}$	(0.00) 1.16	(0.13, 0.39, 0.65) 0.64, 0.90, 1.16, 1.42, 1.68
28.51	—	3	343.93			
28.15	1	4	348.43	$b^2D_{2\frac{1}{2}}$—$x^4D^{\circ}_{1\frac{1}{2}}$		
23.42	—	2	407.64			
22.68	40	100	416.92	$a^4F_{3\frac{1}{2}}$—$y^2D^{\circ}_{2\frac{1}{2}}$	(0.00w) 1.52 A[1]	(0.08, 0.22, 0.38)0.86, 1.00, 1.16, 1.30, 1.46, 1.60
20.43	3	10	445.18	$a^4P_{2\frac{1}{2}}$—$y^4D^{\circ}_{3\frac{1}{2}}$		
20.23	100	200	447.69	$a^2D_{2\frac{1}{2}}$—$z^4G^{\circ}_{3\frac{1}{2}}$	(0.00w) 0.88A[2]	(0.06, 0.18, 0.30) 0.76, 0.88, 1.00, 1.12, 1.24, 1.36
19.23	—	2	460.26			
18.03	—	3	475.36			
16.90	—	2	489.59	$b^4P_{1\frac{1}{2}}$—$v^2F^{\circ}_{2\frac{1}{2}}$		
16.08	2	12	499.92	$a^2P_{1\frac{1}{2}}$—$y^4P^{\circ}_{2\frac{1}{2}}$		
14.77	6	40	516.45	$a^2G_{3\frac{1}{2}}$—$w^2F^{\circ}_{3\frac{1}{2}}$		
14.48	15	80	520.10	$a^4P_{2\frac{1}{2}}$—$x^2D^{\circ}_{2\frac{1}{2}}$	(0.36) 1.33B	(0.08, 0.24, 0.40) 1.02, 1.18, 1.34, 1.50, 1.66
13.87	40	70	527.80	$a^2D_{2\frac{1}{2}}$—$z^2F^{\circ}_{2\frac{1}{2}}$	(0.68) 1.13 Bw	(0.14, 0.44, 0.72) 0.46, 0.74, 1.04, 1.32, 1.62
10.23	—	3	573.82			
09.61	1	3	581.67	$a^4F_{1\frac{1}{2}}$—$z^4P^{\circ}_{1\frac{1}{2}}$		
08.00	30	80	602.07	$a^4F_{2\frac{1}{2}}$—$z^4P^{\circ}_{2\frac{1}{2}}$	(0.84) 1.30B	(0.20, 0.58, 0.98) 0.48, 0.86, 1.26, 1.64, 2.04
2807.53	—	4	608.03	$z^4D^{\circ}_{2\frac{1}{2}}$—5		
2799.77	—	4	706.72	$z^4F^{\circ}_{3\frac{1}{2}}$ —4		
98.50	—	6 h	722.92			
94.11	—	1	779.04	$y^2D^{\circ}_{1\frac{1}{2}}$—6		
93.62	—	3	785.32	$z^2P^{\circ}_{1\frac{1}{2}}$—7		
92.81	1	4	795.70	$b^4F_{1\frac{1}{2}}$—$x^4D^{\circ}_{2\frac{1}{2}}$		
90.44	1	5	826.10	$a^2F_{3\frac{1}{2}}$—$x^2F^{\circ}_{2\frac{1}{2}}$		
89.81	3	20	834.19	$a^2F_{2\frac{1}{2}}$—$y^4D^{\circ}_{2\frac{1}{2}}$		
89.73	10	60	835.22	$a^2G_{3\frac{1}{2}}$—$z^2H^{\circ}_{4\frac{1}{2}}$	(0.00) 1.15	(0.06, 0.16, 0.28, 0.38) 0.64, 0.76, 0.86, 0.98, 1.08, 1.20, 1.30, 1.42
89.51	7	50	838.04	$a^2G_{4\frac{1}{2}}$—$w^2F^{\circ}_{3\frac{1}{2}}$	(0.00) 1.07	(0.02, 0.08, 0.12, 0.18) 0.96, 1.00, 1.06, 1.10, 1.16, 1.20, 1.26, 1.30
87.92	—	2	858.48	$b^2D_{2\frac{1}{2}}$—$w^2F^{\circ}_{3\frac{1}{2}}$		
86.31	2	12	879.20	$a^2P_{0\frac{1}{2}}$—$w^2D^{\circ}_{1\frac{1}{2}}$		
85.89	—	2	884.61			
84.47	—	3	902.91	$a^2F_{2\frac{1}{2}}$—$x^2D^{\circ}_{1\frac{1}{2}}$		
77.31	—	3	35995.46			
75.27	4	15	36021.92	$a^4P_{0\frac{1}{2}}$—$x^2D^{\circ}_{1\frac{1}{2}}$		
74.02	15	60	038.15	$a^4F_{4\frac{1}{2}}$—$y^4F^{\circ}_{3\frac{1}{2}}$	(0.00w) 1.83A[2]	(0.08, 0.22, 0.38, 0.52) 0.80, 0.96, 1.10, 1.26, 1.40, 1.56, 1.70, 1.86
73.50	5	20	044.91	$a^4P_{0\frac{1}{2}}$—$z^4S^{\circ}_{1\frac{1}{2}}$		
73.36	50	250	046.72	$a^4F_{3\frac{1}{2}}$—$z^4G^{\circ}_{4\frac{1}{2}}$	(0.00) 1.09	(0.03, 0.09, 0.15, 0.21) 0.96, 1.02, 1.08, 1.14, 1.20, 1.26, 1.32, 1.38
72.34	4	20	059.99	$b^2D_{1\frac{1}{2}}$—$y^4P^{\circ}_{1\frac{1}{2}}$		
70.44	6	30	084.72	$a^4P_{1\frac{1}{2}}$—$x^2D^{\circ}_{2\frac{1}{2}}$		
69.69	—	3	094.49			
67.34	1	8	125.14	$b^2D_{2\frac{1}{2}}$—$x^4P^{\circ}_{1\frac{1}{2}}$		
64.89	1	10	157.14	$a^2G_{4\frac{1}{2}}$—$z^2H^{\circ}_{4\frac{1}{2}}$		
64.48	—	2	162.51	$b^4F_{1\frac{1}{2}}$—$x^4P^{\circ}_{2\frac{1}{2}}$		
61.20	—	6	205.46	$b^2G_{3\frac{1}{2}}$—$u^2D^{\circ}_{2\frac{1}{2}}$		
59.09	—	2	233.15			
56.92	5	30	261.66	$a^2G_{3\frac{1}{2}}$—$y^2G^{\circ}_{3\frac{1}{2}}$		
53.84	—	1	302.22	$z^2D^{\circ}_{2\frac{1}{2}}$—4		
53.61	—	10 h	305.25			
52.57	—	7 h	318.97			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
51.81	20	80	329.00	$a^4F_{4½}—y^2F^0_{3½}$	(0.00w) 1.82A[2]	(0.08, 0.26, 0.42, 0.60) 0.74, 0.90, 1.08, 1.24, 1.42. 1.58, 1.76, 1.92
51.21	—	3	336.92	$b^2G_{4½}—v^2F^0_{3½}$		
48.70	—	2	370.10			
48.41	—	2	373.94	$a^2D_{1½}—z^2P^0_{1½}$		
40.42	—	7	479.98	$b^4F_{3½}—v^2D^0_{2½}$		
39.08	—	3	497.83			
38.77	60	150	501.96	$a^4F_{2½}—z^2F^0_{3½}$	(0.00) 1.19	(0.03, 0.09, 0.15) 0.97, 1.03, 1.09, 1.15, 1.21, 1.27.
35.76	—	4	542.12	$z^2D^0_{1½}—3$		
35.12	1	7	550.67	$b^2D_{1½}—x^2F^0_{2½}$		
32.98	—	20 h	579.29	$z^2F^0_{2½}—9$		
32.68	3	15	583.30	$a^2G_{4½}—y^2G^0_{3½}$		
31.16	2	10	603.66	$b^2D_{2½}—y^2G^0_{3½}$		
29.47	—	5	626.32			
28.25	—	2	642.70			
27.18	—	4	657.08			
18.51	40?	50	773.98	$b^2D_{1½}—w^2D^0_{1½}$	(0.00) 1.08	(0.04, 0.10) 0.90, 1.06, 1.14.
17.90	—	10	782.23	$z^4D^0_{3½}—6$ / $z^2D^0_{2½}—5$		
14.60	—	2	826.94	$z^2P^0_{0½}—5$		
13.51	—	10	841.74	$a^2P_{0½}—x^4D^0_{0½}$		
12.43	20	60	856.40	$a^4F_{2½}—y^2D^0_{2½}$	(0.00) 1.08	(0.01, 0.03, 0.05) 1.03, 1.05, 1.07, 1.09, 1.11.
12.13	1	15	860.48	$a^2F_{2½}—y^4D^0_{3½}$		
11.96	2	20	862.79	$a^2P_{1½}—x^4D^0_{2½}$		
10.65	—	5	880.61			
10.00	—	8	889.45	$z^4F^0_{3½}—3$		
06.71	10	100	934.29	$a^4P_{2½}—y^4P^0_{1½}$	(0.00 w) 1.16 A[1]	(0.08, 0.24) 1.18, 1.34, 1.50, 1.66.
03.18	1	10	982.52	$a^2G_{3½}—x^4D^0_{2½}$		
02.52	—	3	36991.55			
01.55	—	1	37004.83	$y^4F^0_{4½}—19$		
2700.98	—	4 h	012.50			
2687.22	—	5 h	202.15			
86.55	—	2	211.43			
85.72	—	3	222.93	$z^2F^0_{2½}—10$		
85.22	4	30	229.86	$a^2P_{1½}—x^4P^0_{2½}$	(0.00) 1.27	(0.04, 0.14) 1.08, 1.16, 1.26, 1.34.
84.02	1	7	246.50	$a^2P_{1½}—x^2P^0_{1½}$		
83.35	40	150	255.80	$a^2F_{3½}—x^2F^0_{3½}$	(0.18) 1.14	(0.03, 0.09, 0.15, 0.21) 0.96, 1.02, 1.08, 1.14, 1.20, 1.26, 1.32.
82.99	—	2	260.80			
78.42	2	10	324.37	$b^2D_{2½}—x^4D^0_{2½}$		
77.95	—	2	330.92			
77.56	2	10	336.36	$a^4F_{3½}—y^4F^0_{3½}$		
76.63	2	20	349.33	$a^2G_{3½}—x^4F^0_{3½}$		
75.21	—	2	369.15			
74.52	—	1	378.80	$b^4P_{1½}—u^2D^0_{2½}$		
72.05	—	1	413.34	$z^4G^0_{4½}—16$		
71.25	7	15	424.55	$a^4P_{2½}—x^2F^0_{2½}$		
70.33	—	3	437.44	$z^2F^0_{2½}—11$		
69.57	2	7	448.10	$b^4F_{1½}—w^2P^0_{1½}$		
69.01	20	25	455.95	$a^2D_{2½}—z^4P^0_{2½}$		
67.53	—	6 h	476.74			
67.15	—	2 h	482.07			
66.95	—	2 h	484.88	$z^2D^0_{2½}—3$		
65.98	15	50	498.52	$a^4P_{1½}—y^4P^0_{1½}$	(0.00) 1.63	(0.06, 0.16) 1.52, 1.64, 1.74.
64.03	—	2	525.97	$z^4D^0_{1½}—2$		
61.89	30	100	556.14	$a^4F_{3½}—y^2F^0_{2½}$	(0.00 W) 1.72 A[2]	(0.14, 0.42, 0.70) 0.53, 0.81, 1.09, 1.37, 1.65, 1.93.
60.53	—	3	575.33	$z^4F^0_{1½}—1$		
59.69	—	4 h	587.20			
57.85	20	50	613.22	$a^4F_{2½}—y^4F^0_{1½}$		
57.50	7	20	618.17	$a^2F_{3½}—w^2D^0_{2½}$		
55.68	—	3 h	643.95			
55.41	—	4	647.78	$a^4P_{2½}—w^2D^0_{1½}$		
55.06	—	2 h	652.74			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
53.06	—	2 h	681.12			
52.86	—	4	683.96	$z^2F^3_{3½}$—5		
52.33	—	5	691.49	$b^2D_{2½}$—$x^4P^5_{2½}$		
51.79	—	1	699.17	$z^4D^5_{½}$—4		
51.17	10	40	707.98	$b^2D_{2½}$—$x^2P^5_{1½}$	(0.00) 1.22	(0.04, 0.14) **1.14**, 1.24, 1.34 1.44.
50.28	—	6 h	720.65			
49.15	5	20	736.73	$b^2D_{1½}$—$x^4D^5_{0½}$		
48.06	—	3 h	752.27			
47.30	60	200	763.10	$a^4F_{4½}$—$y^4F^5_{4½}$	(0.40) 1.28 Bw	(0.05, 0.15, 0.25, 0.35, 0.45) 0.88, 0.98, 1.08, 1.18, **1.28**, 1.38, 1.48, 1.58, 1.68.
44.46	—	3	803.65	$z^4D^5_{2½}$—7		
41.41	100	400	847.31	$a^4F_{4½}$—$z^4G^5_{5½}$	(0.00) 1.14	(**0.03**, 0.09, 0.15, 0.21, 0.27) **1.00**, 1.06, 1.12, 1.18, 1.24, 1.30, 1.36, 1.42, 1.48, 1.54.
38.71	80	200	886.03	$a^2D_{1½}$—$y^2D^5_{1½}$	(0.00) 0.81	(0.00) 0.80.
37.53	—	2	902.98			
36.69	—	2	915.05	$y^2D^5_{1½}$—10		
35.79	6	30	928.00	$a^2G_{3½}$—$y^2G^5_{4½}$	(0.00 w) 1.61 A[2]	(0.08, 0.24, 0.40, 0.56) 0.52, 0.68, 0.84, 1.00, 1.16, 1.32, 1.48, **1.64**.
32.02	—	4	982.32	$b^4F_{2½}$—$v^2D^5_{2½}$		
31.52	—	1	37989.54	$a^4P_{1½}$—$x^2F^5_{2½}$		
30.18	—	4	38008.89			
29.77	—	2	014.82			
29.52	—	4	018.43			
27.83	—	1	042.88	$y^2D^5_{2½}$—16		
26.96	10	20	055.48	$a^4F_{3½}$—$y^4F^5_{3½}$		
25.56	2	10	075.77	$a^2P_{0½}$—$x^4P^5_{0½}$		
24.83	1?	3 h	086.36	$z^4G^5_{3½}$—12		
22.75	50	150	116.56	$a^4F_{1½}$—$y^2D^5_{2½}$	(**0.34**, 0.96) 1.49, **2.11**	(**0.32**, 0.94) 0.14, 0.76, 1.40, **2.02**.
21.81	—	5 h	130.22	$y^2D^5_{1½}$—11		
20.96	1	5	142.59	$a^2F_{3½}$—$w^2F^5_{3½}$		
17.17	—	1	197.82			
14.30	3	10	239.75	$a^2P_{0½}$—$x^4P^5_{1½}$		
13.61	20	100	249.85	$a^2G_{4½}$—$y^2G^5_{4½}$	(0.18) 1.10 B	(0.02, 0.08, 0.12, 0.18, **0.22**) 0.90, 0.96, 1.00, 1.06, **1.10**, 1.16, 1.20, 1.26, 1.30
11.65	—	1	278.55			
09.29	—	4	313.17	$b^4F_{2½}$—$x^4D^5_{2½}$		
07.26	5	20	343.00	$b^2D_{1½}$—$w^2D^5_{2½}$		
7.03	50	150	346.38	$a^4F_{3½}$—$y^2F^5_{3½}$	(0.26) 1.14	(0.04, 0.10, 0.18, 0.24) 0.98, 1.06, 1.12, **1.20**, 1.26, 1.34 1.40
06.38	40	100	355.94	$a^2D_{2½}$—$z^2F^5_{3½}$	(0.00) 1.02	(**0.03**, 0.09, 0.15) **0.97**, 1.03, 1.09, 1.15, 1.21, 1.27
03.50	1	1	398.37	$a^2D_{1½}$—$z^4P^5_{0½}$		
2600.30	—	4	445.62			
2599.20	6	25	461.89	$a^2F_{3½}$—$z^2H^5_{4½}$		
98.84	—	3	467.22	$a^4P_{0½}$—$y^4P^5_{1½}$		
96.68	—	5 h	499.21			
96.37	—	4 h	503.81			
95.61	1	8	515.08	$a^2P_{1½}$—$w^2P^5_{1½}$		
93.40	—	3	547.90			
91.32	15	30	578.84	$a^2D_{1½}$—$z^2F^5_{2½}$		
90.97	—	1	584.05	$z^4P^5_{2½}$—15 $z^2F^5_{2½}$—13		
87.51	—	2	635.64			
86.81	—	2	646.10			
86.27	—	2	654.16			
84.05	—	2	687.37			
82.90	—	3	704.60			
82.51	25	60	710.44	$a^2D_{2½}$—$y^2D^5_{2½}$		
81.70	—	1	722.59	$z^4G^5_{2½}$—6		
81.22	—	1	729.79	$y^4F^5_{3½}$—19		
80.09	—	3	746.75			
79.08	—	4 h	761.92			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
78.15	20	60	775.90	$a^4F_{2\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$		
77.53	—	2	785.23	$z^2P^o_{1\frac{1}{2}}$—9		
76.83	20	80	795.76	$a^4F_{4\frac{1}{2}}$—$z^2G^o_{3\frac{1}{2}}$		
75.50	—	15 h	815.80	$z^4G^o_{3\frac{1}{2}}$—14		
74.28	2?	8	834.19			
73.91	25	100	839.77	$a^2F_{2\frac{1}{2}}$—$x^2F^o_{2\frac{1}{2}}$	(0.16) 1.00	(0.03, 0.09, 0.15) 0.83, 0.89, 0.95, 1.01, 1.07
72.95	3	8	854.26	$a^4P_{2\frac{1}{2}}$—$x^2F^o_{3\frac{1}{2}}$		
71.68	30	150	873.45	$a^4F_{1\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$	(0.18) 0.51	(0.06, 0.18) 0.39, 0.51, 0.63
71.13	—	5	881.76	$z^4D^o_{1\frac{1}{2}}$—3		
70.71	3	10	888.12	$a^2F_{3\frac{1}{2}}$—$y^2G^o_{3\frac{1}{2}}$		
67.46	—	10 h	937.34			
66.63	—	6 h	949.93			
65.24	—	2	971.03	$b^2D_{1\frac{1}{2}}$—$x^4P^o_{0\frac{1}{2}}$		
64.87	—	1	976.65	$b^2D_{2\frac{1}{2}}$—$w^2P^o_{1\frac{1}{2}}$		
63.61	30	50	38995.81	$a^4F_{2\frac{1}{2}}$—$y^2F^o_{2\frac{1}{2}}$	(0.00w) 1.03	(0.06, 0.16, 0.28) 0.78, 0.90, 1.00. 1.12, 1.22
62.81	—	3	39007.98			
61.81	—	3	023.21	$z^2D^o_{1\frac{1}{2}}$—8 $z^2P^o_{0\frac{1}{2}}$—7		
60.74	—	20 h	039.51			
59.20	10	30	063.00	$a^2F_{2\frac{1}{2}}$—$w^2D^o_{1\frac{1}{2}}$	(0.00) 0.86	(0.06, 0.18) 0.80, 0.92, 1.04, 1.16
56.40	—	3 h	105.79			
55.33	—	3 h	122.16			
55.10	—	2	125.68	$a^4F_{1\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$		
53.73	—	2 h	146.67			
52.36	—	8 h	167.68			
51.85	3	10	175.51	$a^4P_{1\frac{1}{2}}$—$x^4D^o_{0\frac{1}{2}}$		
51.40	40	150	182.42	$a^2G_{4\frac{1}{2}}$—$z^2H^o_{3\frac{1}{2}}$		
49.14	—	4	217.15	$a^4P_{2\frac{1}{2}}$—$w^2D^o_{2\frac{1}{2}}$		
48.97	—	3	219.77	$b^4F_{1\frac{1}{2}}$—$v^2D^o_{2\frac{1}{2}}$		
48.52	1	3	226.69	$a^2D_{1\frac{1}{2}}$—$z^4P^o_{1\frac{1}{2}}$		
48.20	10	30	231.62	$a^4P_{2\frac{1}{2}}$—$x^4D^o_{1\frac{1}{2}}$		
44.82	—	6 h	283.72			
43.93	—	2	297.46	$z^4P^o_{2\frac{1}{2}}$—16		
43.13	—	3 h	309.82	$z^4D^o_{2\frac{1}{2}}$—6		
37.34	20	30	399.52	$a^4F_{1\frac{1}{2}}$—$y^2P^o_{0\frac{1}{2}}$		
34.33	—	10	446.31			
32.97	6	8	467.49	$a^2D_{2\frac{1}{2}}$—$y^4F^o_{1\frac{1}{2}}$		
31.19	30	50	495.24	$a^4F_{2\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$		
29.78	—	5 h	517.25			
28.24	—	3 h	541.32	$z^2D^o_{1\frac{1}{2}}$—6		
26.28	—	3 h	572.00			
23.89	—	1	609.47	$a^3F_{3\frac{1}{2}}$—$x^4D^o_{2\frac{1}{2}}$		
23.64	—	10 h	613.39			
21.72	—	5 h	643.47	$z^2F^o_{3\frac{1}{2}}$—17		
21.49	10	20	647.16	$a^2P_{1\frac{1}{2}}$—$w^2P^o_{0\frac{1}{2}}$		
20.41	—	6 h	664.15			
16.88	60	150	719.78	$a^2D_{2\frac{1}{2}}$—$y^2P^o_{1\frac{1}{2}}$	(0.00) 1.14	(0.03, 0.09) 1.09, 1.15, 1.21, 1.27.
15.49	10	30	741.73	$a^4P_{2\frac{1}{2}}$—$w^2F^o_{3\frac{1}{2}}$		
13.02	25	80	780.78	$a^4F_{3\frac{1}{2}}$—$y^4F^o_{4\frac{1}{2}}$	(0.00) 1.21	(0.00) 1.23.
12.68	20	60	786.17	$a^4F_{2\frac{1}{2}}$—$y^2F^o_{3\frac{1}{2}}$	(0.00) 1.36	(0.05, 0.15, 0.25) 0.91, 1.01, 1.11, 1.21, 1.31, 1.41.
10.36	—	4	822.93	$a^2P_{0\frac{1}{2}}$—$x^2P^o_{1\frac{1}{2}}$		
05.17	—	3 h	905.43	$z^4F^o_{2\frac{1}{2}}$—2		
01.34	—	2	966.53	$z^2D^o_{2\frac{1}{2}}$—8		
2500.75	10	25	39975.95	$a^2F_{3\frac{1}{2}}$—$x^4P^o_{2\frac{1}{2}}$		
2498.56	—	4 h	40010.99	$z^2P^o_{0\frac{1}{2}}$—8		
96.99	30	60	036.15	$a^4F_{1\frac{1}{2}}$—$y^4F^o_{2\frac{1}{2}}$		
94.37	—	10 h	078.20	$z^4F^o_{2\frac{1}{2}}$—4		
90.23	—	2	144.82	$a^4P_{0\frac{1}{2}}$—$x^4D^o_{0\frac{1}{2}}$		
86.08	—	1	211.83	$z^2P^o_{1\frac{1}{2}}$—12		
85.83	—	3	215.87	$z^4G^o_{2\frac{1}{2}}$—9		
83.34	10	20	256.19	$a^4F_{1\frac{1}{2}}$—$y^2F^o_{2\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
82.49	—	2	269.98	$a^2F_{2½}$—$x^2F^o_{3½}$		
81.44	10	25	287.02	$a^2P_{1½}$—$v^2D^o_{2½}$		
78.56	10	15	333.82	$b^2D_{1½}$—$x^4D^o_{2½}$		
76.05	—	3 h	374.71	$z^4D^o_{1½}$—7		
74.09	1	5	406.69	$a^2G_{3½}$—$v^2D^o_{2½}$		
73.90	8	20	409.79	$a^4P_{1½}$—$x^4P^o_{0½}$		
72.54	—	2	432.02	$z^4D^o_{3½}$—14		
71.78	—	2 h	444.45			
71.21	—	3 h	453.78			
69.17	40	60	487.20	$a^4P_{2½}$—$y^2G^o_{3½}$		
67.96	20	20	507.04	$a^2D_{1½}$—$z^4P^o_{2½}$		
65.06	10	25	554.69	$a^2F_{3½}$—$y^2G^o_{4½}$		
64.19	60	100	569.01	$a^4F_{4½}$—$y^4D^o_{3½}$	(0.00) 1.30	(0.02, 0.06, 0.10, 0.14) **1.19**, 1.23, 1.27, 1.31, 1.35, 1.39, 1.43, 1.47
63.96	10?	20	572.80	$a^4P_{1½}$—$x^4P^o_{1½}$		
62.77	—	3 h	592.40	$z^4G^o_{3½}$—15		
61.73	1	25 h	609.95	Hf III?		
60.49	70	80	630.01	$a^2D_{2½}$—$y^4F^o_{2½}$		
59.46	3	4	647.03	$a^2F_{2½}$—$x^4D^o_{1½}$		
56.97	—	2 h	688.22			
56.65	—	3 h	693.52	$z^2F^o_{3½}$—18		
55.20	5	5	717.55	$b^2D_{1½}$—$x^2P^o_{1½}$		
53.98	4	15	737.79	$a^2G_{3½}$—$x^4D^o_{3½}$		
53.34	10	40	748.42	$b^2D^o_{2½}$—$v^2D^o_{2½}$		
52.47	—	15	762.87	Hf III?		
52.30	10	12	765.70	$a^4P^o_{0½}$—$x^4D^o_{1½}$		
50.05	—	3 h	803.13	$z^4D^o_{0½}$—5 $z^4D^o_{2½}$—9		
49.43	30	40	813.47	$a^4F_{3½}$—$z^2G^o_{3½}$		
47.25	40	50	849.81	$a^2D_{2½}$—$y^2F^o_{2½}$		
46.72	—	2	858.66	$a^4G^o_{2½}$—10		
45.58	—	2 h	877.70			
43.25	—	2	916.69			
41.05	1	10 hl	40953.56			
36.16	—	2	41035.75			
34.76	10	20	059.35	$a^2G_{4½}$—$x^4D^o_{3½}$		
33.87	—	3 h	074.36	$z^4G^o_{2½}$—11		
33.56	30	50	079.59	$b^2D_{2½}$—$x^4D^o_{3½}$		
32.86	—	2 h	091.41	$a^2P_{½}$—$w^2P^o_{0½}$		
30.16	—	1	137.06	$b^4F_{3½}$—$v^2F^o_{2½}$		
28.99	20	30	156.87	$a^2F_{2½}$—$w^2F^o_{3½}$		
26.86	—	6 h	193.00			
25.98	50	70	207.94	$a^4P_{2½}$—$x^4D^o_{2½}$		
24.01	1	8 h	241.42	$z^4F^o_{1½}$—2		
22.86	—	2 h	261.00	$z^4F^o_{2½}$—3		
20.76	2	4	296.79	$a^4F_{4½}$—$v^2F^o_{3½}$		
20.21	—	2?	306.17	$z^4G^o_{3½}$—16		
17.69	70	80	349.22	$a^2D_{2½}$—$y^4F^o_{3½}$		
17.23	—	6	357.09			
17.03	—	2	360.51			
16.88	—	2 h	363.08	$z^4D^o_{1½}$—8		
15.95	15	20	379.00	$a^4P_{0½}$—$x^4P^o_{0½}$		
13.86	—	2?	414.82	$z^4F^o_{1½}$—4		
13.33	4	15	423.92	$a^2F_{2½}$—$x^4P^o_{1½}$		
12.04	—	2	446.07	$z^4D^o_{2½}$—10		
10.13	40	60	478.91	$a^4F_{4½}$—$z^2G^o_{4½}$		
09.53	—	2 h	489.24			
06.43	30	50	542.68	$a^4P_{0½}$—$x^4P^o_{1½}$		
05.42	60	100	560.13	$a^4F_{3½}$—$y^4D^o_{2½}$	(0.00) 1.12	(0.05, 0.15, 0.25) **0.98**, 1.08, 1.18, 1.28, 1.38, 1.48
04.56	10	20	574.99	$a^4P_{2½}$—$x^4P^o_{2½}$		
03.60	6	10	591.59	$a^4P_{2½}$—$x^2P^o_{1½}$		
02.02	—	3 h	618.95	$z^4F^o_{4½}$—16		
2400.79	40	50	640.27	$a^2D_{2½}$—$y^2F^o_{3½}$		
2397.20	—	2 h	702.62			
96.01	—	1	723.33	$z^2F^o_{3½}$—19		
94.96	—	2 h	741.62			
93.83	80	100	761.33	$a^2D_{1½}$—$y^2D^o_{2½}$	(0.00 w) 1.44 A[2]	(**0.14**, 0.42) 0.66, 0.94, 1.22, **1.50**

TABLE 1.—*First spark spectrum of hafnium* (Hf II]—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
93.36	50	80	769.53	$a^4F_{2½}$—$y^4D^o_{1½}$	(0.00) 1.00	(0.05, 0.15) 0.91, 1.01, 1.11, 1.21
93.17	20	40	772.84	$a^4P_{1½}$—$x^4D^o_{2½}$		
92.00	—	3 h	793.27			
86.32	—	3?	892.74	$z^2D^o_{1½}$—11		
85.78	—	3	902.22	$a^2F_{2½}$—$y^2G^o_{3½}$		
85.18	—	4 h	912.76			
84.57	—	2 h	923.48			
81.51	—	1 h	977.35	$z^2D^o_{2½}$—9		
81.00	20	40	986.34	$b^2D_{1½}$—$w^2P^o_{1½}$		
80.30	30	60	41998.68	$a^4F_{1½}$—$y^4D^o_{0½}$		
78.81	—	2 h	42024.99	$z^4F^o_{3½}$—10		
77.97	—	7	039.83			
72.33	3	4	139.77	$a^4P_{1½}$—$x^4P^o_{2½}$		
71.93	—	3 h	146.87			
71.40	6	8	156.29	$a^4P_{1½}$—$x^2P^o_{1½}$		
68.47	—	4 h	208.44	$z^4D^o_{3½}$—15		
67.63	2	3	223.41	$a^2P_{0½}$—$w^2P^o_{0½}$		
65.98	8	10	252.86	$a^4F_{2½}$—$z^2G^o_{3½}$		
62.32	—	2	318.31			
51.21	100	150	518.26	$a^2D_{1½}$—$y^4F^o_{1½}$		
49.33	—	2 h	552.28	$z^4G^o_{3½}$—17		
47.44	80	120	586.54	$a^4F_{3½}$—$y^4D^o_{3½}$		
45.41	4	5	623.39	$a^2F_{2½}$—$x^4D^o_{2½}$		
43.32	60	80	661.41	$a^4F_{3½}$—$x^2D^o_{2½}$		
40.39	—	8 h	714.80			
38.23	—	10 h	754.26	$z^4F^o_{2½}$—7		
37.59	—	3 h	765.97			
37.33	30	30	770.73	$a^2D_{1½}$—$y^2P^o_{1½}$		
35.50	1	1	804.24	$b^4F_{3½}$—$p^2F^o_{3½}$		
35.24	—	2	809.00	$z^4F^o_{3½}$—12		
33.79	—	4 h	835.60	$z^2D^o_{2½}$—11		
32.95	40	50	851.02	$a^4F_{1½}$—$z^2S^o_{½}$		
32.44	7	10	860.39	$a^4P_{2½}$—$w^2P^o_{1½}$		
32.18	2		865.16	$z^4F^o_{1½}$—17		
29.09	2	2 h	922.03	$z^4D^o_{1½}$—16		
25.40	1	?	990.13	$a^2F_{2½}$—$x^4P^o_{2½}$		
24.89	40	80	42999.56	$a^4F_{2½}$—$y^4D^o_{2½}$		
24.50	20	40	43006.78	$a^2F_{2½}$—$x^2P^o_{1½}$		
23.25	40	60	029.91	$a^4F_{1½}$—$y^4D^o_{1½}$		
22.47	60	60	044.36	$a^2D_{1½}$—$y^2P^o_{0½}$		
21.14	50	60	069.03	$a^4F_{2½}$—$x^2D^o_{1½}$		
18.49	8	10	118.25	$b^2D_{1½}$—$w^2P^o_{0½}$		
16.49	10	20	155.47			
05.34	6	8	364.18	$a^2F_{3½}$—$x^4D^o_{3½}$		
04.50	3	3 h	379.98			
03.21	4	4 h	404.28	$z^2D^o_{2½}$—12		
2302.11	5	6	425.01	$a^4P_{1½}$—$w^2P^o_{1½}$		
2298.78	6	8	487.91	$a^2P_{1½}$—$u^2D^o_{1½}$		
98.33	25	50	496.43	$a^4F_{3½}$—$z^2G^o_{4½}$		
96.13	5	6 h	538.10	$z^4F^o_{3½}$—14		
92.77	3	3 h	601.90	$z^4G^o_{3½}$—18		
92.34	2	2 h	610.07			
91.64	30	40	623.39	$a^2D_{2½}$—$y^4D^o_{1½}$		
88.63	5	6	680.76	$a^2D_{1½}$—$y^4F^o_{2½}$		
85.43	6	6 h	741.92	$z^4F^o_{2½}$—8		
84.60	20	30	757.81	$b^2D_{1½}$—$v^2D^o_{2½}$		
81.81	5	6 h	811.30			
77.16	150	150	900.76	$a^2D_{1½}$—$y^2F^o_{2½}$		
76.43	4	4 h	914.83	$z^4F^o_{1½}$—18		
74.64	15	20	949.39	$b^2D_{2½}$—$u^2D^o_{1½}$		
73.15	40	60	43978.19	$a^4F_{4½}$—$x^2F^o_{3½}$		
71.14	2	2 h	44017.11	$z^4D^o_{1½}$—10		
70.68	6	7	026.03	$a^4F_{2½}$—$y^4D^o_{3½}$		
69.86	8	8 h	041.93			
68.47	2	2 h	068.92			

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
67.91	3	3 h	079.80			
67.58	3	3 h	086.21			
67.35	3	3 h	090.68	$z^4F^i_{1\frac{1}{2}}-7$		
66.83	60	80	100.79	$a^4F_{2\frac{1}{2}}-x^2D^o_{2\frac{1}{2}}$		
66.52	30	40	106.82	$a^2D_{2\frac{1}{2}}-z^2G^o_{3\frac{1}{2}}$		
63.36	2	2 h	168.40	$z^4D^o_{3\frac{1}{2}}-17$		
61.54	3	3 h	203.94			
60.25	2	2 h	229.17			
58.68	15	20	259.91	$a^4F_{1\frac{1}{2}}-y^4D^o_{2\frac{1}{2}}$		
57.89	10	15	275.39	$a^4F_{2\frac{1}{2}}-w^2P^i_{1\frac{1}{2}}$		
56.26	1	2	307.37	$b^4F_{2\frac{1}{2}}-v^2F^o_{3\frac{1}{2}}$		
55.15	40	60	329.18	$a^4F_{1\frac{1}{2}}-x^2D^i_{1\frac{1}{2}}$		
54.00	60	80	351.80	$a^4F_{1\frac{1}{2}}-z^4S^o_{1\frac{1}{2}}$		
51.85	8	9	394.14	$a^4P_{0\frac{1}{2}}-w^2P^i_{1\frac{1}{2}}$		
49.82	5	5 h	434.19			
44.23	4	4 h	544.85			
43.18	15	20	565.70	$a^4F_{3\frac{1}{2}}-x^2F_{2\frac{1}{2}}$		
39.86	5	6	631.75	$a^4P_{2\frac{1}{2}}-v^2D_{2\frac{1}{2}}$		
36.34	4	4 h	702.00			
35.41	3	20 h	720.59	Hf III?		
31.41	3	3 h	800.75	$z^4D^i_{1\frac{1}{2}}-12$		
28.78	7	8	853.61	$a^2D_{2\frac{1}{2}}-y^4D_{2\frac{1}{2}}$		
28.45	4	4 h	860.25			
28.18	6	8	865.69	$a^4F_{4\frac{1}{2}}-w^2F^o_{3\frac{1}{2}}$		
25.35	6	7	922.74	$a^2D_{2\frac{1}{2}}-x^2D^i_{1\frac{1}{2}}$		
24.29	10	10 H	944.14	$z^4F^i_{1\frac{1}{2}}-19$		
23.36	4	5	44962.94	$a^4P_{2\frac{1}{2}}-x^4D^o_{3\frac{1}{2}}$		
20.48	7	8 h	45021.25			
18.37	10	15	064.07	$a^2G_{3\frac{1}{2}}-v^2F^o_{2\frac{1}{2}}$		
17.66	2	2h	078.50	$z^4F^i_{1\frac{1}{2}}-8$		
12.45	25	30	184.64	$a^4F_{4\frac{1}{2}}-z^2H^i_{4\frac{1}{2}}$		
11.86	5	6	196.69	$a^4P_{1\frac{1}{2}}-v^2D^o_{2\frac{1}{2}}$		
10.82	2	2 h	217.95	$z^4D^o_{3\frac{1}{2}}-18$		
06.59	2	2 h	304.62			
06.11	10	10 h	314.47	$z^4F^o_{3\frac{1}{2}}-15$		
03.85	3	3	360.94	$a^4F_{1\frac{1}{2}}-x^2D^o_{2\frac{1}{2}}$		
02.99	3	3 h	378.64	$z^4D^i_{1\frac{1}{2}}-13$		
2201.67	3	3	405.85	$b^2D_{2\frac{1}{2}}-v^2F^o_{2\frac{1}{2}}$		
2199.84	4	4 h	443.62			
99.57	8	8 h	449.19	$z^4D^o_{2\frac{1}{2}}-16$		
99.40	7	8	514.78	$a^4F_{2\frac{1}{2}}-y^4P^i_{1\frac{1}{2}}$		
91.79	10	15	610.51	$a^4F_{4\frac{1}{2}}-y^2G^o_{3\frac{1}{2}}$		
91.27	5	5 h	621.33			
90.22	30	30	643.20	$a^2D_{1\frac{1}{2}}-y^4D^o_{0\frac{1}{2}}$		
88.87	5	6 h	671.34			
84.95	6	6 h	753.27	$z^4F^o_{2\frac{1}{2}}-9$		
84.31	6	8	766.68	$b^4F_{1\frac{1}{2}}-u^2D^o_{2\frac{1}{2}}$		
81.94	3	3 h	816.38			
80.22	2	2 h	852.52			
78.90	60	80	880.30	$a^2D_{2\frac{1}{2}}-y^4D^o_{3\frac{1}{2}}$		
75.36	25	30	954.95	$a^2D_{2\frac{1}{2}}-x^2D^o_{2\frac{1}{2}}$		
73.44	15	20	45995.54	$a^4F_{3\frac{1}{2}}-x^2F^o_{3\frac{1}{2}}$		
72.96	5	5 h	46005.70	$a^4F_{2\frac{1}{2}}-x^2F^o_{2\frac{1}{2}}$		
71.89	6	6 h	028.36	$z^4F^o_{3\frac{1}{2}}-16$		
70.22	20	30	063.78	$a^2P_{0\frac{1}{2}}-u^2D^i_{1\frac{1}{2}}$		
62.48	15	15	228.63	$a^4F_{2\frac{1}{2}}-w^2D^i_{1\frac{1}{2}}$		
61.61	10	10 h	247.24	$z^4D^o_{3\frac{1}{2}}-19$		
58.12	15	15 h	322.02			
56.44	25	35	358.10	$a^4F_{3\frac{1}{2}}-w^2D^o_{2\frac{1}{2}}$		
55.51	1	1	378.10	$a^2F_{2\frac{1}{2}}-x^4D^o_{3\frac{1}{2}}$		
54.66	4	4 h	396.39	$z^4F^o_{2\frac{1}{2}}-10$		
50.30	10	10 h	490.45			
50.07	5	5	495.43	$a^2D_{1\frac{1}{2}}-z^2S^o_{0\frac{1}{2}}$		
49.86	6	6 h	499.97			
44.73	3	3 h	611.18	$z^4F^o_{2\frac{1}{2}}-11$		
44.17	6	6 h	623.31	$z^2D^o_{2\frac{1}{2}}-16$		
41.84	20	20	674.06	$a^2D_{1\frac{1}{2}}-y^4D^i_{1\frac{1}{2}}$		
39.24	30	40	730.78	$a^2G_{3\frac{1}{2}}-v^2F^o_{3\frac{1}{2}}$		
37.22	6	6	774.95	$a^4F_{1\frac{1}{2}}-y^4P^i_{1\frac{1}{2}}$		
34.53	15	20	833.89	$a^2P_{1\frac{1}{2}}-u^2D^o_{2\frac{1}{2}}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
33.36	4	4 h	859.57			
32.28	9	10	883.30	$a^4F_{3½}$—$w^2F^o_{3½}$		
30.09	8	8 h	931.50			
29.10	60	100	953.32	$a^2G_{3½}$—$u^2D^o_{2½}$		
27.50	5	5 h	46988.62			
26.61	7	8 h	47008.28			
24.59	50	80	052.97	$a^2G_{4½}$—$v^2F^o_{3½}$		
23.68	40	40	073.13	$b^2D_{2½}$—$v^2F^o_{3½}$		
22.94	15	15 h	089.54	$z^4F^o_{1½}$—9		
17.95	5	5 h	200.47	$a^4F_{3½}$—$z^2H^o_{1½}$		
16.80	4	(?)	226.11			
15.61	4	(?)	252.67			
15.02	20	20	265.85	$a^4F_{1½}$—$x^2F^o_{2½}$		
14.62	2	(?)	274.79	$z^4F^o_{3½}$—17		
10.42	15	15	368.86	$a^2D_{2½}$—$y^4P^o_{1½}$		
08.50	15	10 h	411.99			
2107.47	60	60	435.15	$a^4F_{2½}$—$x^2F^o_{3½}$		
2098.91	2	(?)	628.59	$a^4F_{3½}$—$y^2G^o_{3½}$		
96.18	100	150	690.61	$a^2F_{3½}$—$v^2F^o_{3½}$		
94.33	3	(?)	732.73	$z^4F^o_{1½}$—10		
93.22	7	(?)	758.04	$z^4F^o_{2½}$—13		
90.83	40	40	812.63	$a^4F_{2½}$—$x^4D^o_{1½}$		
89.95	30	30	832.76	$a^4P_{2½}$—$u^2D^o_{1½}$		
89.38	3	(?)	845.80			
88.77	50	50	859.77	$a^2D_{2½}$—$x^2F^o_{3½}$		
87.66	4	(?)	885.22			
86.80	8	4	904.95	$a^2D_{1½}$—$y^4D^o_{2½}$		
86.29	12	(?)	916.66			
84.94	1	(?)	947.68	$z^4F^o_{1½}$—11		
84.45	2	(?)	956.65			
83.80	40	30	973.91	$a^2D_{1½}$—$x^2D^o_{1½}$		
82.80	15	8	47996.94	$a^2D_{1½}$—$z^4S^o_{1½}$		
79.72	3	(?)	48068.01			
79.11	3 d	(?)	082.11	$a^2D_{2½}$—$w^2D^o_{1½}$		
76.70	3	(?)	137.90			
76.04	4	(?)	153.21			
68.84	20	4 h	320.77			
68.76	3	(?)	322.63	$a^4F_{2½}$—$w^2F^o_{3½}$		
68.58	5	(?)	326.85			
66.20	2	(?)	382.50			
65.55	2	(?)	397.72	$a^4P_{1½}$—$u^2D^o_{1½}$		
64.78	15	4	415.77	$b^2D_{1½}$—$v^2F^o_{2½}$		
64.43	2	(?)	423.98			
63.23	3	(?)	452.13	$a^4F_{1½}$—$x^4D^o_{0½}$		
61.39	4	(?)	495.38			
60.49	7	(?)	516.55	$z^4F^o_{1½}$—12		
57.39	3	(?)	589.65	$a^4F_{2½}$—$x^4P^o_{1½}$		
55.30	4	(?)	639.05			
54.86	2	(?)	48649.47			
39.08	6	2	49025.90			
37.32	2	(?)	068.25	$a^4F_{2½}$—$y^2G^o_{3½}$		
36.24	3	(?)	094.27	$z^4F^o_{1½}$—13		
29.88	5	(?)	248.07	$a^2F_{2½}$—$u^2D^o_{1½}$		
28.18	25	15	289.34	$a^4P_{2½}$—$v^2F^o_{3½}$ $a^2D_{2½}$—$x^2F^o_{3½}$		
23.36	2	(?)	406.74			
20.07	3	(?)	487.20			
13.38	2	(?)	651.61	$a^2D_{2½}$—$w^2D^o_{3½}$		
2012.78	10	4	49666.41	$a^2D_{2½}$—$x^4D^o_{1½}$		
λ_{vac}						
2005.99	—	1	49851	$a^4F_{1½}$—$x^4P^o_{1½}$		
1993.10	—	3	50173	$a^4F_{2½}$—$x^2P^o_{1½}$		
64.23	—	15	911	$a^2D_{1½}$—$x^2F^o_{2½}$		
63.75	—	9	923	$a^2D_{2½}$—$y^2G^o_{3½}$		
62.44	—	5	50957	$a^4P_{2½}$—$v^2F^o_{3½}$		

TABLE 1.—*First spark spectrum of hafnium* (Hf II)—Continued

λ_{air}	Intensity		ν_{vac} cm^{-1}	Term combinations	Zeeman effects	
	Arc	Spark			Observed	Computed
55.66	—	12	51134	$a^2D_{1½}$—$w^2D^{\circ}_{1½}$		
22.74	—	12	52009	$a^2D_{2½}$—$x^4P^{\circ}_{2½}$		
22.11	—	9	026	$a^2D_{2½}$—$x^2P^{\circ}_{1½}$		
19.52	—	20	096	$a^2D_{1½}$—$x^4D^{\circ}_{0½}$		
09.46	—	4	371	$a^2F_{2½}$—$v^2F^{\circ}_{3½}$		
1901.40	—	6	593	$a^2F_{2½}$—$u^2D^{\circ}_{2½}$		
1897.51	—	3	52701	$a^2D_{1½}$—$w^2D^{\circ}_{2½}$		
69.24	—	7	53498	$a^2D_{1½}$—$x^2P^{\circ}_{1½}$		
16.26	—	4	55058	$a^2D_{1½}$—$x^4P^{\circ}_{2½}$		
16.05	—	3	065	$a^2D_{2½}$—$v^2D^{\circ}_{2½}$		
1815.71	—	9	55075	$a^2D_{1½}$—$x^2P^{\circ}_{1½}$		
1774.81	—	10	56344	$a^2D_{1½}$—$w^2P^{\circ}_{1½}$		
1716.23	—	6	58267	$a^2D_{2½}$—$u^2D^{\circ}_{1½}$		
1679.58	—	3	59538	$a^4F_{2½}$—$v^2F^{\circ}_{3½}$		
1628.91	—	12	61390	$a^2D_{2½}$—$v^2F^{\circ}_{3½}$		
1623.06	—	12	61612	$a^2D_{2½}$—$u^2D^{\circ}_{2½}$		

V. STRUCTURE OF THE Hf II SPECTRUM

In the process of atom building as first outlined by Bohr [10] the group of 14 rare-earth elements occurring between lanthanum (57) and hafnium (72) is accounted for by the successive addition of *f*-type electrons in the shell with total quantum number 4 while the (remaining) valence electrons $5d$ and $6s^2$ remain unchanged. Thus the first $4f$ electron appears in cerium (58), the shell of 14 such electrons is filled in lutecium (71), and the addition of $5d$ electrons is resumed in hafnium (72) so that its configuration of valence electrons may be presumed to be $5d^26s^2$. If the hafnium atom is ionized by the removal of one of its *d* electrons the outer structure is identical with that of neutral lanthanum, and except for a scale factor due to difference in nuclear charge the Hf II and La I spectra may be expected to be similar in structure. In this case the *displacement law* of spectroscopy can be tested with a displacement of 15 units in atomic number, much like the comparison of Zr II with La I, which is a displacement of 17 units in the other direction. When the structures of Hf II and La I spectra are compared they are found to exhibit the most striking similarity that has ever been observed in comparisons of this type. This is illustrated in figures 1 and 2, which are energy diagrams of these 2 spectra. The diagram for La I (fig. 1) is reproduced from the paper by Russell and Meggers [11], while the diagram for Hf II (fig. 2) is similarly constructed except that the ordinates are doubled in numerical value. For a comparison of details, however, it is necessary to refer to the term tables for these two spectra. The chief differences will be found to consist (1) of a group of low terms (associated with d^3 electrons) which has been established for Hf II but not for La I, and (2) more middle terms involving an *f* electron are found in La I than in Hf II.

The modern theory of spectral structure [12] which correlates spectral terms with configurations of valence electrons indicates that for 3

[10] N. Bohr, Z. Physik, 9,1(1922).
[11] H. N. Russell and W. F. Meggers, BS J.Research 9,647(1932); RP497.
[12] F. Hund, Linienspektren und periodisches System der Elemente, Julius Springer, Berlin(1927).

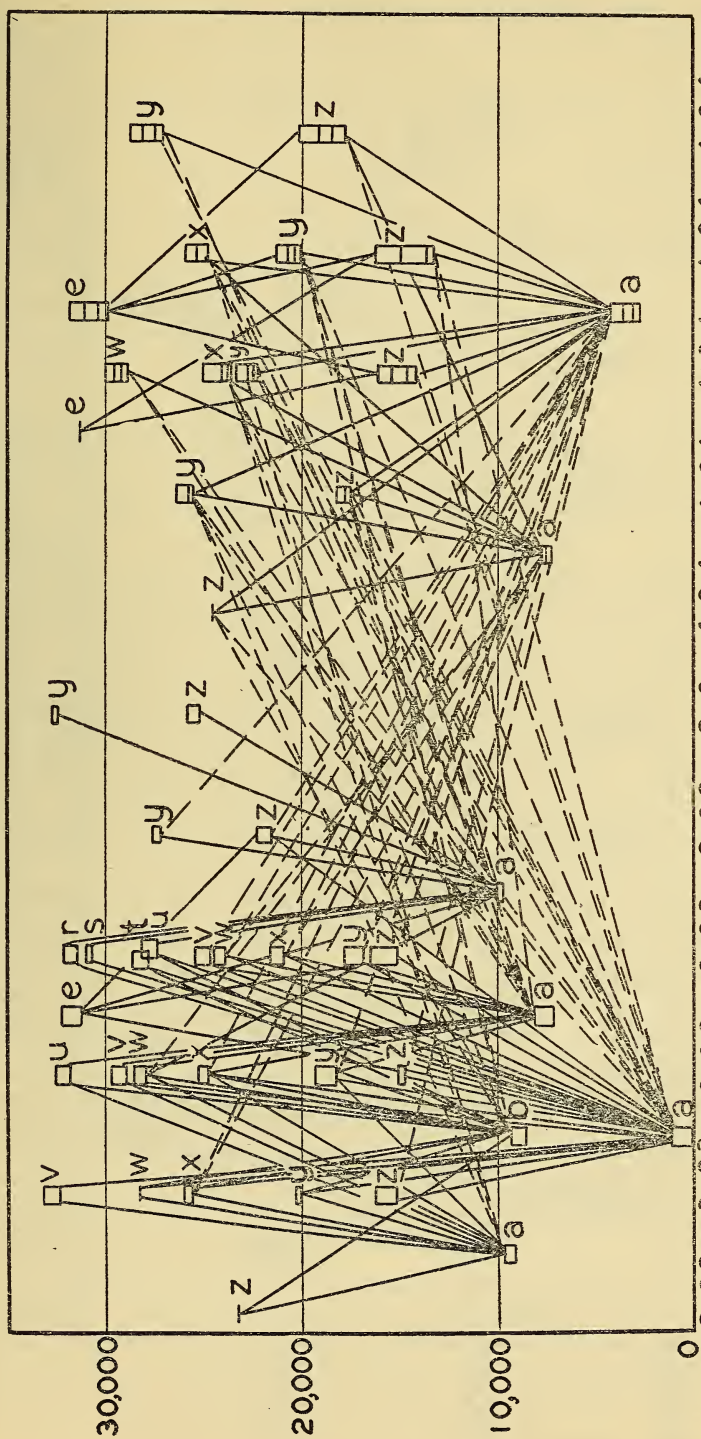

FIGURE 1.—*Terms and combinations of the* La I *spectrum.*

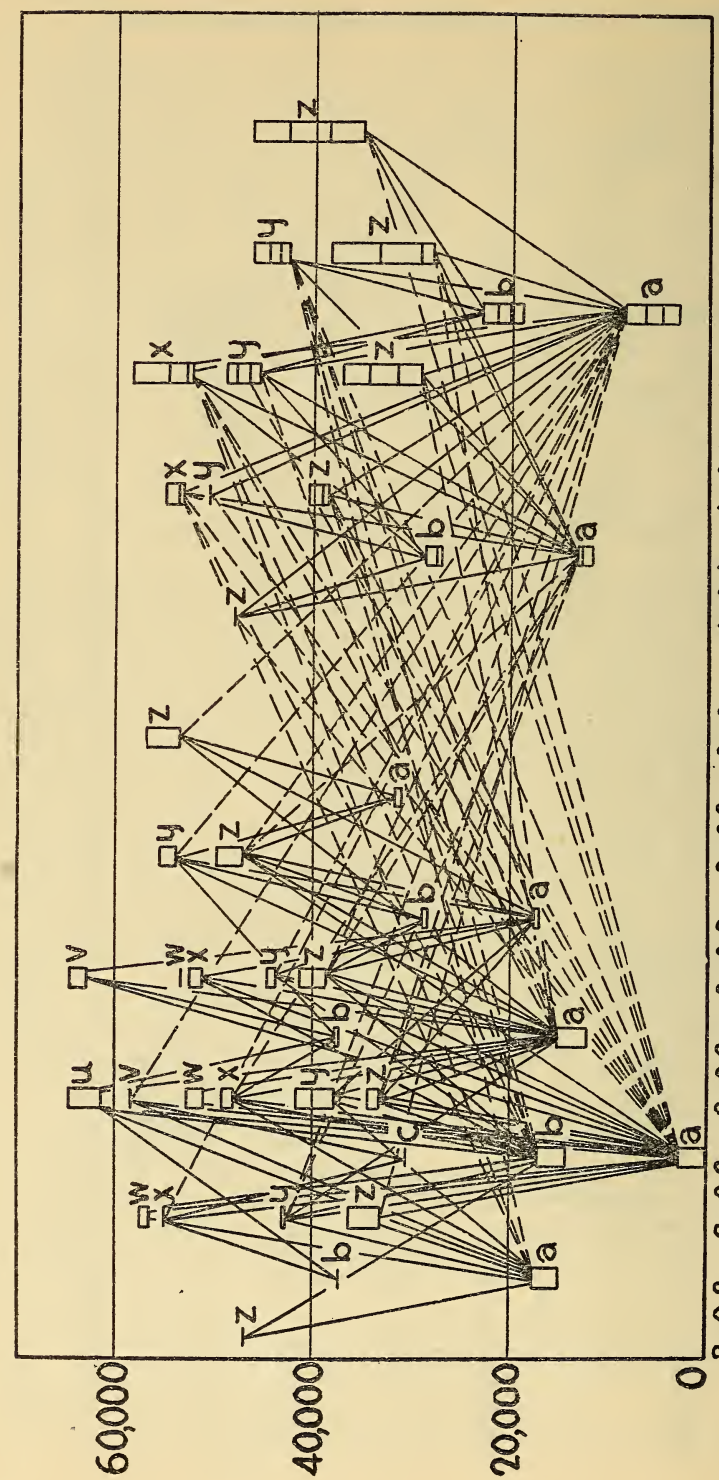

FIGURE 2.—*Terms and combinations of the* Hf II *spectrum.*

electron spectra such as Hf II, etc., one may expect to find the terms listed in table 2 as the most prominent.

TABLE 2.—*Theoretical terms in the* Hf II *spectrum*

Electron configuration	Spectral terms	Electron configuration	Spectral terms
$5d\ 6s^2$	^2D	$5d^2\ 6p$	$^2D^0, {}^2F^0, {}^2G^0, {}^4D^0, {}^4F^0, {}^4G^0$ $^2S^0, {}^2P^0, {}^2D^0, {}^4S^0, {}^4P^0, {}^4D^0$ $^2F^0, {}^2G^0, {}^2H^0$ $^2P^0, {}^2D^0, {}^2F^0$
$5d^2\ 6s$	$^2S, {}^2D, {}^2G, {}^2P, {}^2F, {}^4P, {}^4F$		
$5d^3$	$^2D, {}^2P, {}^2D, {}^2F, {}^2G, {}^2H, {}^4P, {}^4F$	$5d^2\ 7s$	$^2P, {}^2F, {}^4P, {}^4F$ $^2S, {}^2D, {}^2G$
$5d\ 6s\ 6p$	$^2P^0, {}^2D^0, {}^2F^0, {}^4P^0, {}^4D^0, {}^4F^0$ $^2P^0, {}^2D^0, {}^2F^0$		Etc.

Substitution of an *f*-type electron for any of the above would yield a great variety of additional terms[13] which may be expected to be more important in the spectra of so-called "rare-earth elements", although the first terms of this sort have actually been found in La and Hf spectra.

The first three configurations in table 2 produce 16 terms of low energy content (including the normal state); 14 (all but ^2S ($5d^2 6s$) and the first ^2D (d^3)) have been identified for Hf II. The next two configurations involve a *p*-type electron and are responsible for a host of higher (middle) states which combine with the low even set to account for a large majority of the observed lines, including all of the stronger ones. Additional odd terms may be expected if an electron of type $4f$ ever appears among the valence group. Terms of this type or fragments of them have indeed been found in La I, La II and in Hf II spectra. Normally, there is no $4f$ electron in the La atom and the filled *f* shell in Hf is inactive. But in excited states these atoms may exhibit a $4f$ electron, because in the former case the stage is set for its appearance, while in the latter the displacement of one from the completed shell has the same spectroscopic consequences as the presence of a single one. These terms appear to be somewhat more prominent in La than in Hf spectra.

A total of seventy-odd terms has been established for Hf II. These combine with the low even terms and thus formally account for approximately 900 lines characteristic of singly ionized hafnium atoms. These odd terms also combine with higher even terms forming series with the low ones, but combinations of this sort are always weak so that it is difficult to verify and identify the higher members of series. We have found 19 levels belonging to the high even set, but have experienced great difficulty with their interpretation. Owing to the lack of sufficient criteria for the grouping of these high levels, we shall not essay, at the present time, to go beyond a tentative identification of some of them.

A spectroscopic determination of the ionizing potential of Hf^+ atoms presupposes a correct identification of series forming terms and also a knowledge of the lower energy states of Hf^{++} atoms to which these series converge. Unfortunately, we are unable at the present time to offer more than a tentative interpretation of some of the highest levels

[13] R. C. Gibbs, D. T. Wilber, and H. E. White, Phys. Rev. **29**, 790(1927).

which have been found, and are ignorant of the structure of the Hf III spectrum. However, the remarkable parallelism between Hf II and La I spectra leads us to believe that the structure of Hf III will resemble that of La II when plotted on ordinates having double the numerical value of those for La II. If we make this assumption, and also assume that e^2D and e^4F form series with a^2D and a^4F, respectively, tentative values for the series limits may be calculated. Such calculations lead to an approximate value of 120,000 units for the separation of $a^2D_{1\frac{1}{2}}$ (Hf II) from a^3F_2 (Hf III), so that 14.8 volts may be adopted tentatively as the ionization potential for Hf^+ atoms.

The observed Zeeman effects on hafnium lines have been most helpful in identifying the spectral terms, although most of the patterns are unrecognizable by direct comparison with those of the Landé theory [14] which assumes simple (*LS*) coupling.

It is obvious that the departures from theoretical values derived either from strict (*LS*) or from pure (*JJ*) coupling indicate some intermediate form of vector coupling in hafnium atoms. The Zeeman effect analysis was carried out in the following manner. First, all the magnetic splitting factors (*g* values) which could be derived from fully resolved patterns were calculated, and averaged when more than one value was obtained for a given level. These constitute the *g* values of highest weight. Next the patterns marked A^1 or A^2 (occurring when $\Delta J=\pm 1$) or B (occurring when $\Delta J=0$) were exploited for the calculation of further *g* values, and then the formulas of Shenstone and Blair [15] were applied to the unresolved blends for the calculation of *g* values for the remaining levels. The final *g* values thus derived from the experimental data were used in calculations of the complete patterns which might be expected for each of the lines actually observed in the magnetic field, and these results were placed in the last column of table 1 where they are readily compared with the actual observations, or with patterns resulting from LS coupling.[16]

TABLE 3.—*Relative terms in the* Hf II *spectrum*

Electron configurations	Terms	Level values	Level separations	*g* values		Combinations
				Observed	Landé	
$5d\ 6s^2$	$a^2D_{1\frac{1}{2}}$	0.0	3050.9	0.80	0.80	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, z^4S°, x^4D°, y^4P°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2D°, x^2P°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$a^2D_{2\frac{1}{2}}$	3050.9		1.18	1.20	
$5d^2\ 6s$	$a^4F_{1\frac{1}{2}}$	3644.5	1260.4	0.45	0.40	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, z^4S°, x^4D°, y^4P°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2D°, y^2G°, w^2F°, x^2P°, z^2H°, v^2F°.$
	$a^4F_{2\frac{1}{2}}$	4904.9		1.06	1.03	
	$a^4F_{3\frac{1}{2}}$	6344.4	1439.5	1.23	1.24	
	$a^4F_{4\frac{1}{2}}$	8361.8	2017.4	1.33	1.33	
$5d^26s$	$a^4P_{0\frac{1}{2}}$	11951.7	969.2	2.61	2.67	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, z^4S°, x^4D°, y^4P°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2D°, y^2G°, w^2F°, x^2P°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$a^4P_{1\frac{1}{2}}$	12920.9	564.6	1.69	1.73	
	$a^4P_{2\frac{1}{2}}$	13485.5		1.42	1.60	
$5d^2\ 6s$	$a^2F_{2\frac{1}{2}}$	12070.5	3013.7	0.98	0.86	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, x^4D°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, w^2F°, y^2F°, z^2G°, x^2D°, x^2F° w^2D°, y^2G°, z^2H°, w^2P°, u^2D°, v^2F°.$
	$a^2F_{3\frac{1}{2}}$	15084.2		1.11	1.14	

[14] A. Landé, Zeit. f. Phys. **5**, 231(1921); **15**, 189(1923).
[15] A. G. Shenstone and H. A. Blair, Phil. Mag. 8,765(1929); H. N. Russell, Phys. Rev. **36**, 1590(1930).
[16] C. C. Kiess and W. F. Meggers, BS J.Research **1**, 641(1928); RP23.

TABLE 3.—*Relative terms in the* Hf II *spectrum*—Continued

Electron configurations	Terms	Level values	Level separations	g values		Combinations
				Observed	Landé	
$5d^2\ 6s$	$b^2D_{1½}$	14359.5	3009.4	1.03	0.80	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, x^4D°, y^4P°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2D°, y^2G°, x^2P°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$b^2D_{2½}$	17368.9		1.29	1.20	
$5d^2\ 6s$	$a^2P_{0½}$	15254.4	2576.0	0.74	0.67	$z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, z^4S°, x^4D°, y^4P°, x^4P°, z^2D°, z^2P°, y^2D°, y^2P°, z^2S°, x^2D°, x^2F°, w^2D°, x^2P°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$a^2P_{1½}$	17830.4		1.12	1.33	
$5d^2\ 6s$	$a^2G_{3½}$	17710.7	−321.6	0.92	0.89	$z^4F°, z^4D°, z^4G°, z^4P°, y^4F°, y^4D°, x^4D°, x^4P°, z^2D°, z^2F°, y^2D°, y^2F°, z^2G°, x^2D°, x^2F°, w^2F°, w^2D°, z^2H°, y^2G°, v^2D°, u^2D°, v^2F°.$
	$a^2G_{4½}$	17389.1		1.13	1.11	
$5d^3$	$b^4F_{1½}$	18897.7	1237.3	0.46	0.40	$z^4F°, z^4D°, z^4G°, z^4P°, y^4D°, x^4D°, x^4P°, z^2D°, z^2P°, z^2F°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2F°, w^2D°, y^2G°, z^2H°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$b^4F_{2½}$	20135.0	1502.8	1.01	1.03	
	$b^4F_{3½}$	21637.8	1507.9	1.23	1.24	
	$b^4F_{4½}$	23145.7		1.29	1.33	
$5d^3$	$b^4P_{0½}$	26996.5	288.6			$z^4P°, y^4F°, y^4D°, z^4S°, x^4D°, y^4P°, x^4P°, y^2D°, y^2P°, y^2F°, z^2S°, z^2G°, x^2D°, x^2F°, w^2F°, u^2D°, v^2F°.$
	$b^4P_{1½}$	27285.1		1.76	1.73	
	$b^4P_{2½}$	28547.1	1262.0	1.51	1.60	
$5d^3$	$b^2G_{3½}$	28458.2	−353.3	0.92	0.89	$z^4G°, y^4F°, y^4D°, x^4D°, x^4P°, z^2F°, y^2D°, y^2F°, z^2G°, x^2D°, x^2F°, w^2D°, w^2F°, z^2H°, y^2G°, v^2D°, u^2D°, v^2F°.$
	$b^2G_{4½}$	28104.9		1.05	1.11	
$5d^3$	$a^2H_{4½}$	31877.8	−935.7	1.05	0.91	$z^4G°, y^4F°, x^4D°, z^2G°, x^2F°, w^2F°, z^2H°, y^2G°, v^2F°.$
	$a^2H_{5½}$	30942.1		1.10	1.09	
$5d$	$c^2D_{1½}$	—				$y^4D°, x^4P°, x^2F°, x^2P°, v^2D°, w^2P°.$
	$c^2D_{2½}$	32778.1		1.15	1.20	
$5d^3$	$b^2P_{0½}$	—				$x^4D°, y^4P°, x^2P°, u^2D°.$
	$b^2P_{1½}$	37324.6				
$5d^3$	$b^2F_{2½}$	37398.6	40.9			$x^4D°, x^4P°, x^2D°, x^2F°, w^2F°, y^2G°, z^2H°, y^2G°, v^2D°, w^2P°, u^2D°, v^2F°.$
	$b^2F_{3½}$	37439.5				
$5d\ 6s\ 6p$ $a^3D.p$	$z^4F°_{1½}$	28068.8	1336.4	0.52	0.40	$a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F$, 1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19.
	$z^4F°_{2½}$	29405.2	4371.1	1.08	1.03	
	$z^4F°_{3½}$	33776.3	4409.4	1.26	1.24	
	$z^4F°_{4½}$	38185.7		1.34	1.33	
$5d\ 6s\ 6p$ $a^3D.p$	$z^4D°_{½}$	29160.1	2624.2	0.53	0.00	$a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F$, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19.
	$z^4D°_{1½}$	31784.3	2570.8	1.22	1.20	
	$z^4D°_{2½}$	34355.1	2527.4	1.32	1.37	
	$z^4D°_{3½}$	36882.5		1.39	1.43	
$5d\ 6s\ 6p$ $a^1D.p$	$z^2D°_{1½}$	34124.0	−943.0	0.84	0.80	$a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F$, 2, 3, 4, 5, 6, 8, 9, 11, 12
	$z^2D°_{2½}$	33181.0		1.05	1.20	
$5d\ 6s\ 6p$ $a^3D.p$	$z^2P°_{½}$	33136.3	3237.1	0.29	0.67	$a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, b^4F$, 2, 5, 7, 8, 9, 12.
	$z^2P°_{1½}$	36373.4		1.31	1.33	
$5d^2\ 6p$ $a^3F.p$	$z^4G°_{2½}$	34942.4	3556.1	1.00	0.57	$a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^2G, a^2H$, 1, 2, 3, 6, 9, 10, 11, 12, 14, 15, 16, 17, 18.
	$z^4G°_{3½}$	38498.5		1.06	0.98	
	$z^4G°_{4½}$	42391.0	3892.5	1.17	1.17	
	$z^4G°_{5½}$	46209.1	3818.1	1.27	1.27	

TABLE 3.—*Relative terms in the* Hf II *spectrum*—Continued

Electron configurations	Terms	Level values	Level separations	g values		Combinations
				Observed	Landé	
$5d\ 6s\ 6p$ $a^3D.p$	$z^4P^\circ_{0½}$	38398.6		2.63	2.67	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, 6, 12, 15, 16.
	$z^4P^\circ_{1½}$	39226.4	827.8	1.68	1.73	
	$z^4P^\circ_{2½}$	40506.8	1280.4	1.45	1.60	
$5d\ 6s\ 6p$ $a^3D.p$	$y^2D^\circ_{1½}$	37886.0		0.80	0.80	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, 6, 8, 10, 11, 12, 16.
	$y^2D^\circ_{2½}$	41761.3	3875.3	1.08	1.20	
$5d\ 6s\ 6p$ $a^3D.p$	$z^2F^\circ_{2½}$	38578.7		0.89	0.86	a^2D, a^4F, a^4P, a^2F, b^2D, a^2G, b^4F, b^2G, 5, 6, 9, 10, 11, 13, 15, 17, 18, 19.
	$z^2F^\circ_{3½}$	41407.0	2828.3	1.12	1.14	
$5d^2\ 6p$ $a^3F.p$	$y^4F^\circ_{1½}$	42518.2		0.57	0.40	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, a^2H, 5, 10, 11, 19.
	$y^4F^\circ_{2½}$	43680.7	1162.5	0.98	1.03	
	$y^4F^\circ_{3½}$	44400.0	719.3	1.18	1.24	
	$y^4F^\circ_{4½}$	46125.0	1725.0	1.23	1.33	
$5d\ 6s\ 6p$ $a^1D.p$	$y^2P^\circ_{0½}$	43044.3		0.56	0.67	a^2D, a^4F, a^4P, b^2D, a^2P, b^4F, b^4P.
	$y^2P^\circ_{1½}$	42770.6	−273.7	1.24	1.33	
$5d\ 6s\ 6p$ $a^1D.p$	$y^2F^\circ_{2½}$	43900.6		0.95	0.86	a^2D, a^4F, a^4P, a^2F, b^2D, a^2G, b^4F, b^4P, b^2G, 9, 14, 16.
	$y^2F^\circ_{3½}$	44690.8	790.2	1.16	1.14	
$5d^2\ 6p$ $a^3F.p$	$y^4D^\circ_{0½}$	45643.1		0.47	0.00	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, b^4F, b^4P, b^2G, c^2D.
	$y^4D^\circ_{1½}$	46674.5	1031.4	1.16	1.20	
	$y^4D^\circ_{2½}$	47904.4	1229.9	1.33	1.37	
	$y^4D^\circ_{3½}$	48930.8	1026.4	1.37	1.43	
$5d^2\ 6p$ $a^3P.p$	$z^2\ S^\circ_{0½}$	46495.4		1.68	2.00	a^2D, a^4F, a^4P, b^2D, a^2P, b^4F, b^4P.
$5d^2\ 6p$ $a^3F.p$	$z^2G^\circ_{3½}$	47157.7		1.03	0.89	a^2D, a^4F, a^4P, a^2F, b^2D, a^2G, b^4F, b^4P, b^2G, a^2H, 3, 17.
	$z^2G^\circ_{1½}$	49840.6	2682.9	1.16	1.11	
$5d^2\ 6p$ $b^1D.p$	$x^2D^\circ_{1½}$	47973.4		1.21	0.80	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, b^2F, 5.
	$x^2D^\circ_{2½}$	49005.9	1032.5	1.26	1.20	
$5d^2\ 6p$ $a^3P.p$	$z^4S^\circ_{1½}$	47996.4				a^2D, a^4F, a^4P, a^2P, b^4P.
f^7	$y^4P^\circ_{1½}$	50419.6		1.58	1.73	a^2D, a^4F, a^4P, b^2D, b^4P, b^2P.
$5d^2\ 6p$ $a^3F.p$	$x^2F^\circ_{2½}$	50910.0		0.92	0.86	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, a^2H, c^2D, b^2F.
	$x^2F^\circ_{3½}$	52339.7	1429.7	1.17	1.14	
$5d^2\ 6p$ $a^3F.p$	$w^2D^\circ_{1½}$	51133.5		1.10	0.80	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, b^2F.
	$w^2D^\circ_{2½}$	52702.8	1569.3	1.03	1.20	
$5d^2\ 6p$ $b^1D.p$	$w^2F^\circ_{3½}$	53227.2		1.18	1.14	a^4F, a^4P, a^2F, b^2D, a^2G, b^4F, b^4P, b^2G, a^2H, b^2F.
$5d^2\ 6p$ $a^3P.p$	$x^4D^\circ_{0½}$	52096.5				a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, a^2H, b^2F.
	$x^4D^\circ_{1½}$	52717.1	620.6			
	$x^4D^\circ_{2½}$	54693.2	1976.1	1.30	1.37	
	$x^4D^\circ_{3½}$	58448.1	3754.9	1.12	1.14	
$5d^2\ 6p$ $a^3P.p$	$x^4P^\circ_{0½}$	53330.7		2.58	2.67	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, c^2D, b^2F.
	$x^4P^\circ_{1½}$	53494.1	163.4	1.42	1.73	
	$x^4P^\circ_{2½}$	55060.1	1565.0	1.21	1.60	

TABLE 3.—*Relative terms in the* Hf II *spectrum*—Continued

Electron configurations	Terms	Level values	Level separations	g values		Combinations
				Observed	Landé	
$5d^2\,6p$ $a^1G.p$	$z^2H^{\circ}_{11/2}$	53546.0	3025.5	1.03	0.91	a^4F, a^2F, a^2G, b^4F, b^2G, a^2H, b^2F.
	$z^2H^{\circ}_{13/2}$	56571.5		1.08	1.09	
$5d^2\,6p$ $a^1G.p$	$y^2G^{\circ}_{13/2}$	53972.5	1666.2	1.20	0.89	a^2D, a^4F, a^4P, a^2F, a^2G, b^4F, b^2G, a^2H, b^2F.
	$y^2G^{\circ}_{15/2}$	55638.7		1.08	1.11	
$5d^2\,6p$ $b^1D.p$	$x^2P^{\circ}_{11/2}$	55076.9		1.38	1.33	a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, b^4P, c^2D, b^2P.
$5d^2\,6p$ $a^3P.p$	$w^2P^{\circ}_{3/2}$	57477.6	−1131.9			a^2D, a^4P, a^2F, b^2D, a^2P, b^4F, c^2D, b^2F.
	$w^2P^{\circ}_{1/2}$	56345.7				
f	$v^2D^{\circ}_{3/2}$	58117.3		1.20	1.20	a^2D, a^4P, b^2D, a^2P, a^2G, b^4F, b^2G, c^2D, b^2F.
$5d^2\,6p$ $a^3P.p$	$u^2D^{\circ}_{3/2}$	61318.2	3345.9			a^2D, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, b^2P.
	$u^2D^{\circ}_{5/2}$	64664.1				
$5d^2\,6p$ $a^1G.p$	$v^2F^{\circ}_{5/2}$	62775.0	1667.1			a^2D, a^4F, a^4P, a^2F, b^2D, a^2P, a^2G, b^4F, b^4P, b^2G, a^2H, b^2F.
	$v^2F^{\circ}_{7/2}$	64442.1				
	$1_{2\frac{1}{2}}$	65643.9				z^4F°, z^4D°, z^4G°.
	$(e^4F?)2_{1\frac{1}{2}}$	69310.2	1355.8			z^4F°, z^4D°, z^4G°, z^2D°, z^2P°.
	$(e^4F?)3_{2\frac{1}{2}}$	70666.0				z^4F°, z^4D°, z^4G°, z^2D°, z^2G°.
	$4_{2\frac{1}{2}}$	69483.3				z^4F°, z^4D°, z^2D°.
	$(e^2D?)5_{1\frac{1}{2}}$	69963.2	3701.8			z^4D°, y^4F°, z^2D°, z^2P°, z^2F°, x^2D°.
	$(e^2D?)6_{2\frac{1}{2}}$	73665.0				z^4D°, z^4G°, z^2D°, z^2F°, y^2D°.
	$7_{1\frac{1}{2}}$	72159.2				z^4F°, z^4D°, z^2P°.
	$8_{1\frac{1}{2}}$	73147.3				z^4F°, z^4D°, z^2D°, z^2P°, y^2D°.
	$9_{1\frac{1}{2}}$	75158.4				z^4F°, z^4D°, z^4G° z^2D°, z^2P°, z^2F°, y^2F°.
	$10_{2\frac{1}{2}}$	75801.5				z^4F°, z^4D°, z^4G°, y^4F°, z^2F°, y^2D°.
	$11_{1\frac{1}{2}}$	76016.5				z^4F°, z^4G°, y^4F°, z^2D°, z^2F°, y^2D°.
	$12_{2\frac{1}{2}}$	76585.2				z^4F°, z^4D°, z^4G°, z^2D°, z^2P°, y^2D°.
	$13_{1\frac{1}{2}}$	77163.0				z^4F°, z^4D°, z^2F°.
	$14_{3\frac{1}{2}}$	77314.5				z^4F°, z^4D°, z^4G°, y^2F°.
	$15_{2\frac{1}{2}}$	79090.8				z^4F°, z^4D°, z^4G°, z^4P°.
	$(e^2G?)16_{3\frac{1}{2}}$	79804.6	1246.4			z^4F°, z^4D°, z^4G°, z^4P°, y^2D°, y^2F°.
	$(e^2G?)17_{4\frac{1}{2}}$	81051.0				z^4F°, z^4D°, z^4G°, z^2F°, z^2G°.
	$18_{4\frac{1}{2}}$	82100.5				z^4F°, z^4D°, z^4G°, z^2F°.
	$19_{4\frac{1}{2}}$	83129.8				z^4F°, z^4D°, z^4G°, y^4F°, z^2F°.

All data relating to the established Hf II spectral terms are summarized in table 3 where electron configurations, term symbols, level values, level separations, observed and Landé g values, and combinations appear in successive columns. The symbols associated with energy levels are those now in general use for spectral line classifications.[17]

[17] Phys. Rev. 33, 900(1929).

TABLE 4.—*Zeeman effect* Hf II: *Sums of observed and Landé g values*

Electrons	Terms	J = 4½ Observed	J = 4½ Landé	J = 3½ Observed	J = 3½ Landé	J = 2½ Observed	J = 2½ Landé	J = 1½ Observed	J = 1½ Landé	J = 0½ Observed	J = 0½ Landé	Sum Observed	Sum Landé
$5d\ 6s^2$	a^2D					1.18	1.20	0.80	0.80			1.98	2.00
$5d^2\ 6s$	a^4F	1.33	1.33	1.23	1.24	1.06	1.03	0.45	0.40			4.07	4.00
	a^4P					1.42	1.60	1.69	1.73	2.61	2.67	5.72	6.00
	a^2G	1.13	1.11	0.92	0.89							2.05	2.00
	a^2F			1.11	1.14	0.98	0.86					2.09	2.00
	b^2D					1.29	1.20	1.03	0.80			2.32	2.00
	a^2P							1.12	1.33	0.74	0.67	1.86	2.00
	^2S									(2.00)	2.00	(2.00)	2.00
Sum low terms		2.46	2.44	3.26	3.27	5.93	5.89	5.09	5.06	5.35	5.34	22.09	22.00
$5d\ 6s\ 6p$	$z^4F°$	1.34	1.33	1.26	1.24	1.08	1.03	0.52	0.40			4.20	4.00
	$z^4D°$			1.39	1.43	1.32	1.37	1.22	1.20	0.53	0.00	4.46	4.00
	$z^4P°$					1.45	1.60	1.68	1.73	2.63	2.67	5.76	6.00
	$z^2F°$			1.12	1.14	0.89	0.86					2.01	2.00
	$z^2D°$					1.08	1.20	0.80	0.80			1.88	2.00
	$z^2P°$							1.31	1.33	0.29	0.67	1.60	2.00
	$y^2F°$			1.16	1.14	0.95	0.86					2.11	2.00
	$z^2D°$					1.05	1.20	0.84	0.80			1.89	2.00
	$y^2P°$							1.24	1.33	0.56	0.67	1.80	2.00
Sum odd terms		1.34	1.33	4.93	4.95	7.82	8.12	7.61	7.59	4.01	4.01	25.71	26.00

The so-called "g-sum rule" of Pauli [18] is expected to be valid for all spectra no matter what the nature of the vector coupling may be. This rule may be stated as follows: If among all terms arising through the coupling of one electron, those terms with the same inner quantum number J be grouped, the sum of the g values of the terms in each group must have a value independent of the nature of the coupling, and consequently is, among others, equal to the sum of the Landé g values for a similar group. This rule is tested in table 4 where the observed and Landé g sums are displayed for all groups for which the data are complete. On the whole, the agreement is very satisfactory, the one outstanding discrepancy which occurs for $J=2½$ in the *dsp* configuration remaining unexplained for the present.

In conclusion, we wish to make a statement regarding the spark *raie ultime* of hafnium, i.e., the most persistent spectral line for revealing the presence of ionized hafnium atoms.

Recent progress in analysis of spectral structure and correlation with electron configurations has enabled us to formulate a new rule governing the selection of the *raie ultime* in any spectrum. This rule has been tested in a large number of spectra (which will be detailed in another publication), and is believed to be more fundamental and general than any heretofore proposed for such lines. It may be briefly stated as follows: A *raie ultime* in any spectrum originates with a simple interchange of a single electron between s and p states, usually preferring configurations in which only one electron occurs in such states. In accordance with this rule it may be said that the transition $(5d^26s)\ a^4F_{4½}-(5d^26p)\ z^4G^0_{5½}$, corresponding to the line of wave length 2641.41 A, represents the true *raie ultime* of the Hf II spectrum. It is undoubtedly the most intense line in this spectrum and appears also to be the strongest line ascribable to hafnium in spark spectra of zirconium containing hafnium as an impurity.

Washington, August 8, 1934

[18] W. Pauli, Zeit. f. Phys. 16, 155(1923).